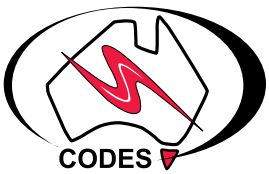
CODES

ARC CENTRE OF EXCELLENCE IN ORE DEPOSITS

ANNUAL REPORT 2010

Australian Government

Australian Research Council



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ARC CENTRE OF EXCELLENCE IN ORE DEPOSITS

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Australian Government

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Vision /

To be the premier international research centre in ore deposit geology.

Mission /

Significantly advance collaborative and innovative ore deposit research for Australian and international researchers and the minerals industry.

Goals /

» Undertake and publish high-quality research.

» Lead the global minerals industry in research on the exploration and recovery of new mineral resources.

» Equip the Australian minerals industry with world-class graduates.

» Communicate the Centre's research to the wider research, industry and general communities.

Contents

DIRECTOR'S REPORT

The past year has seen our Centre build on its strengths, and continue to deliver successful outcomes across a broad range of areas, from fundamental and applied research, through to education, outreach, and technology transfer. It has also been a time when CODES reached a crossroads and was presented with an opportunity to take another major step in its evolution, which I will cover later in this report.

Major research highlights included three high-profile projects coming to a successful conclusion:

» Ore Deposits of SE Asia ended in December, with the final meeting being held at the CODES' UTAS Hub. The 3-year project has substantially enhanced the knowledge of the geology of the region. Outcomes include a new tectonic model for the area, based to a large extent on a new geochemical, geochronological and ore deposits database developed within the project. A proposal to extend the project will be presented to the Science Planning Panel in April.

» AMIRA project P765A – Geochemical and geological halos in green rocks and lithocaps – was successfully concluded, on time and within budget, at a final meeting in Hobart during December. This has been a breakthrough project in the development of mineral chemical vectors that predict the likely direction and distance to porphyry-style mineralised centres. By using advances in LA-ICP-MS, the research team established that subtle hypogene geochemical dispersion halos can be detected several kilometres beyond the limits of geochemical anomalies that are detected by conventional rock-chip sampling techniques; thereby extending the detectable geochemical footprint of porphyry mineralised centres.

» AMIRA project P962 - Ni-PGE potential of mafic and ultramafic magmas – was finalised at a meeting in Hobart in April. Important achievements included the development of a new model of sulfur saturation in mafic magmas, which (for the first time) takes into account the effect of melt Ni content.

Our researchers also continued to break new ground in other areas, challenging long standing theories and pioneering new models for some of the world's major ore bodies. For example, research conducted by Jeff Foster and Dave Hutchinson, making extensive use of CODES' LA-ICP-MS facilities, has led to a new model for the formation of the Merensky Reef in South Africa's Bushveld Complex - the world's richest source of platinum group metals.

A statistic that stands out in this year's report is the figure of 197 reports delivered to industry. This compares to 105 in 2009, and represents the highest total since CODES was formed over 20 years ago. The figure is high partly because a number of major projects drew to a close, but it is also indicative of increasingly strong links with industry, and our focus on technology transfer that delivers tangible outcomes.

Although this figure is pleasing, there is no doubt that this level of output has had an impact on our production of refereed journal articles, which has dropped below target. Quality journal output is increasingly important due to the ERA benchmarking program of the ARC. Therefore, we have made a firm commitment to improve our A and A* outputs to reach the higher levels that were achieved in recent years.

Staff maintained their record of regularly receiving top accolades. This year it was the turn of Research Fellow, Jacqueline Halpin, who was awarded one of only two Research Excellence Awards presented to Early Career Researchers. We have also continued to attract top geoscientists to add to our pool of world-class researchers. Late in the year, we were successful in securing the services of renowned environmental geochemist, Bernd Lottermoser, who has joined the team on the Recovery Program. This is a key appointment in helping us achieve our objective of building on our research activities in the field of environmental geosciences. Bernd is employed under the UTAS New Stars Program and will commence duties in January 2011.

Over the past two years, we have been very fortunate to have Jamie and Clara Wilkinson from Imperial College London on the CODES' team. They have contributed in a number of areas, particularly the AMIRA porphyry project P765A. We plan for this collaboration to continue to bear fruit into the future.

It was an exceptional year for our graduate research activities with 15 PhD students having theses under examination, nine of whom graduated. Fifty-four students were enrolled on the HDR program, which included 37 international students representing 18 nationalities. Fourteen of these students were at least partly funded by CODES' scholarships. The Centre has built a strong reputation for attracting international students, but it was pleasing to note that of the seven new students in this year's cohort three were from Australia, the first in a number of years to be recruited nationally.

The Master of Economic Geology Program, co-ordinated by Tony Webster, also continued to go from strength to strength. For the first time, the number of students topped the 50 mark, a figure that represents over 60% of enrolments on the national program. Three major short courses were held during the year and all were full to capacity.

Our outreach activities continued to grow and included a mix of activities across a broad range of demographic groups, from pre-schoolers through to retirees. Teachers, and particularly career advisors, were also important target groups. A highlight was the introduction of the 'Gemnasium', which is a large bed of brightly polished rocks from around the world. This new feature is particularly popular with the younger age groups, who love fossicking through the colourful stones. The rocks are also mounted on display boards and used in a variety of educational tools that teach the children about geology while they are having fun.

It has been a mixed year in terms of finance. There was a significant dip in industry funding, but there were a number of mitigating factors, which are covered in detail in the financial section of this report. Many of these factors will fall away in the future; therefore, the forecast is more promising in the longer term. On a positive note, we were pleased to announce that MMG has joined our list of Industry Partners, which now consist of ten major mining companies.

Overall, it has been a good year that has resulted in success in a wide range of areas; but it has also been a year that I believe will prove pivotal for our continued growth and evolution. Although CODES has secured an extension of its Centre of Excellence funding until 2013, there is no provision under current ARC rules for a further extension beyond that date. Therefore, management decided that it was important to start planning for our future beyond 2013. That process included meetings with all our key stakeholders, including our Advisory Board, the ARC, industry, and collaborating institutions. As a result of these consultations, it was decided that CODES would start an application process for becoming a CRC.

This is seen as a natural progression for the Centre, which started out as a Key Centre in 1989, became a Special Research Centre in 1997, and progressed to its current status as Centre of Excellence in 2005. Although CODES can still pride itself on its success in merging fundamental and applied research, there is no doubt that our links with industry, which have always been strong, have increased even further over the years. For example, the ratio of industry funding has continued to grow, and has been our largest source of income for the past few years. Not surprisingly, there has been a corresponding increase in the number of industry-related projects over the same period. The large increase in Industry Reports that I mentioned earlier bears testament to that trend, which has also led to research outcomes that are in high demand by industry, and provided us with the opportunity to become more involved in the commercialisation of our research.

As a CRC adopts a more commercial, industry-focussed model, I believe (along with the majority of our stakeholders) that this application is a logical step in our development. Therefore, I ask everyone associated with CODES to embrace the opportunities that this presents and look forward, as I do, to the next chapter in our story.

Ross R Large
Director and Chief Operations Officer

FUNDAMENTAL RESEARCH TO APPLIED OUTCOMES

~ an outline of CODES' structure

In Brief /

CODES is the Australian Research Council Centre of Excellence in Ore Deposits, based at the University of Tasmania. Formed in 1989, the Centre has grown substantially over the years and is now widely regarded as a global leader in ore deposit research. In 2010, it was home to 64 highly qualified research staff and 116 postgraduate students, further cementing its position as the largest university-based team of ore deposit researchers in the world.

Highly productive worldwide collaborations have been developed with approximately 70 industry companies, plus a host of joint research initiatives with 79 institutes and universities – 19 in Australia and 60 overseas. It currently has 51 major research projects spanning 28 countries, and is the leading academic group to publish in *Economic Geology*.

In 2010, its reports to industry almost doubled to reach a total of 197, helping to strengthen the Centre's reputation for delivering excellence in terms of technology transfer.

2010 Key Statistics /

64 Academic research staff

116 Postgraduate students

51 Major research projects

40 Publications in journals

197 Research reports to industry

28 Countries involved

Industry funding **$3.4 million**

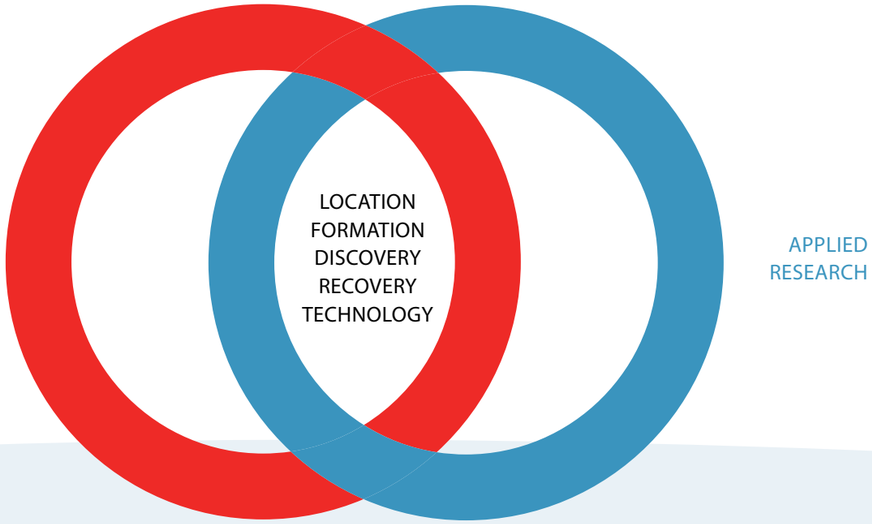
ARC funding **$3.1 million**

UTAS funding **$2.1 million**

Worldwide collaborations:

70 Industry (approximately)

79 Institutes and universities



Framework for Leading Research /

CODES' research is built around five major programs that cover a wide spectrum of the geosciences including igneous petrology, geochemistry, melt/fluid inclusion research, volcanology, structural geology, tectonics, geophysics, ore petrology and geometallurgy.

The strategic focus of the Centre is based on a holistic, multidisciplinary approach that covers all elements of ore deposit research, from fundamental research through to applied research outcomes. Its modus operandi is to use advances in the fundamental research and technology programs to drive innovative team-based applied research, linked with industry. This is achieved through the five major research programs – Location, Formation, Discovery, Recovery and Technology.

» **Location** builds on expertise in magmatic, volcanic and tectonic processes in diverse tectonic settings – includes groundbreaking research into magmas associated with nickel-PGE mineralisation. The program provides a better understanding of the links between tectonic setting, magmatism, basin evolution, and ore deposit formation in modern and ancient terrains.

» **Formation** develops practical, process-based ore genesis models to help explorers understand the formation of deposits. CODES has built a fine reputation for its research into process-based exploration models for hydrothermal and magmatic ore deposits. This research is enhanced by employing an integrated approach to solving metal source-transport-trap problems and utilising targeted collaborations with other leading research institutes.

» **Discovery** focuses on the acquisition, processing and interpretation of scientific ore deposit data to assist in the discovery of minerals. CODES' innovative work in the field of geology and geochemistry is augmented by its pioneering work in ore deposit geophysics. This research is strongly supported by the mining industry, which recognises that increasing efficiencies in the discovery of deep earth resources is essential to the long-term growth of the industry.

» **Recovery** is an integrated, cross-disciplinary field that seeks to enhance mineral processing techniques and optimise mineral recovery rates. CODES works in collaboration with the Julius Kruttschnitt Mineral Research Centre (JKMRC) at the University of Queensland, which is recognised as a world leader in metallurgical research. The alliance of these two benchmark organisations has created a synergy that has resulted in a number of innovative improvements to recovery methods that have provided wide ranging benefits throughout the industry.

» **Technology** uses a combination of traditional and cutting-edge technological developments to improve the understanding and, subsequently, advance the exploration and exploitation of minerals. CODES is at the forefront of advances in spatially resolved, inductively coupled plasma mass spectrometry (ICP-MS), nuclear microprobe (NMP), and synchrotron-based non-destructive focused-beam spectroscopy and software development.

Teamwork /

The Centre continues to place a great emphasis on teamwork. Co-operation and collaboration are openly encouraged, both within CODES and in its interactions with a host of national and international organisations. This team approach is inherent in the five research programs, which foster teamwork through an overlapping and interlinked process that follows a logical progression from area selection through to exploration, discovery and recovery.

Hub, Nodes and International Partners /

CODES is based at the University of Tasmania, with satellite facilities, known as nodes, at the University of Queensland, University of Melbourne, Australian National University, and CSIRO Exploration and Mining.

This structure provides an exceptionally strong mix of skills and facilities by combining the research strengths of CODES' UTAS Hub with the diverse range of expertise available through the nodes.

The nodes' strengths include:

» Metallurgy and mineral processing – JKMRC (University of Queensland).

» Structure of ore deposits (Australian National University).

» Isotope geochemistry (University of Melbourne).

» Micro-beam analytical techniques (CSIRO Exploration and Mining).

The strengths of these Australian nodes are complemented by two strong partnerships with the University of British Columbia and the Colorado School of Mines, which provide an ideal platform for international research projects and augment the Centre's access to the latest technology.

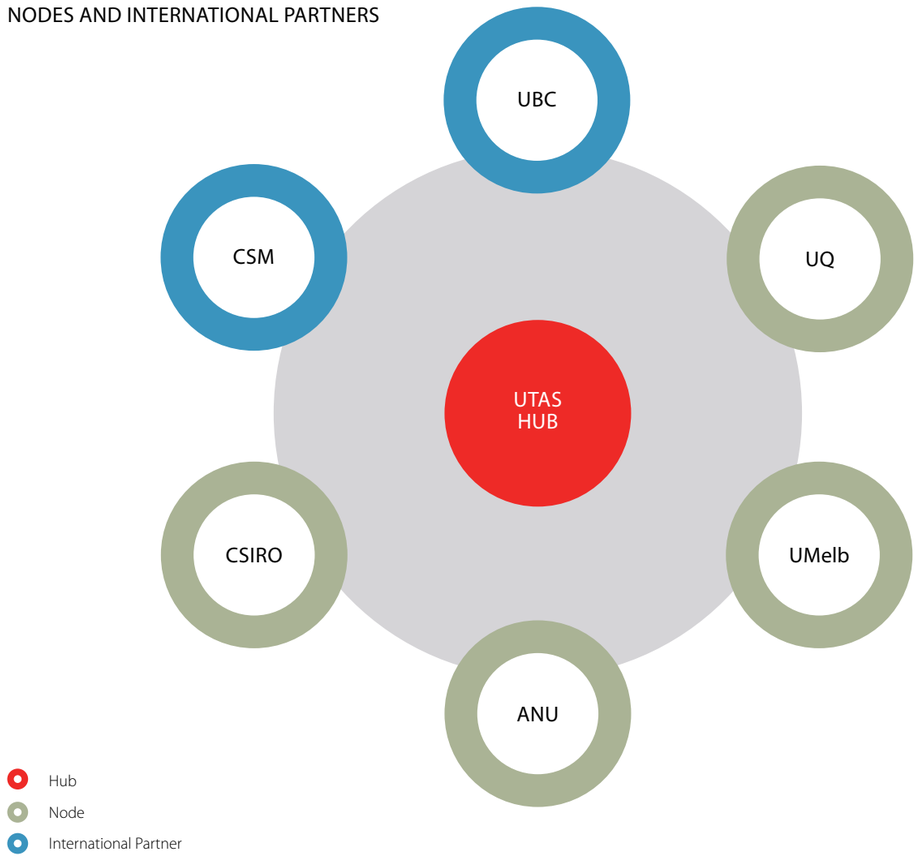
Collaborations with these two international partners include:

» Joint research projects in mineral deposits, geochronology and geophysics (University of British Columbia).

» Joint research projects with Murray Hitzman and his team (Colorado School of Mines).

In addition to these international partnerships, CODES collaborates with 79 universities and institutes, plus approximately 70 industry companies worldwide.

NODES AND INTERNATIONAL PARTNERS



STAFF & MANAGEMENT

Centre Director

Centre Director, Ross Large, is responsible for the scientific leadership and operational management of the Centre. He is supported in these duties by Bruce Gemmell (Deputy Director), the Advisory Board and the Executive Committee.

Advisory Board

The Advisory Board meets annually to review the progress of the Centre and to advise on future directions. The Board is composed of major industry partners, University of Tasmania senior management, and key national geoscience organisations. It is chaired by John Dow, a geologist with significant management experience in the minerals industry and a strong international reputation in economic geology.

Science Planning Panel

The Science Planning Panel meets annually for a one-day forum of presentations relating to the Centre's scientific research progress and to discuss potential new research projects. The membership is wider than that of the Advisory Board and includes a representative from all partner companies. The Panel is designed to provide industry with an opportunity to influence future research directions of the Centre.

Centre Research Committee

The Centre Research Committee includes all collaborating partner chief investigators. It meets annually to discuss research progress, new research opportunities and particularly to focus on effective collaborative activities across all Centre partners.

Executive Committee

The Executive Committee consists of the Centre Director, Deputy Director, five program leaders, Graduate Research Co-ordinator and administrative managers. It meets approximately six times a year, working closely with the Director to develop the Centre's goals, strategies and performance indicators.

Staff Appointments 2010

Ian Little was appointed as Research Technician in the ICP-MS laboratory, where his main role is the preparation and analysis of geological digests.

Janina Micko has joined the team on the Formation Program, after completing her PhD at UBC (MDRU) earlier in the year. Janina is working on a collaborative project with Newcrest Mining entitled: Exploring the porphyry environment.

Ralf Schaa completed his PhD at UTAS (CODES) in 2010, and was appointed as a Research Fellow to continue his work in the Discovery Program on project P3A1C (AMIRA P1022) - Rapid approximate inversion of TEM data.

Andy Wakefield has been appointed to the position of Geophysics Technician, responsible for field assistance and the maintenance of geophysics equipment. In collaboration with ANU, Andy will be involved in the set-up and deployment of a passive seismic recording network throughout northern Tasmania, Bass Strait and southern Victoria.

Director, Professor Ross Large, BSc Hons (UTAS), PhD (UNE)	Volcanic-hosted and sediment-hosted base metal and gold ores

ACADEMIC/RESEARCH STAFF AT UTAS

Dr Sharon Allen, BSc (Massey), MSc (Auckland), PhD (Monash)	Volcanic facies analysis
Dr Mike Baker, BSc Hons (Sydney), PhD (UTAS)	Igneous petrology, mineral chemistry
Associate Professor Ron Berry, BSc, PhD (Flinders)	Structure of mineralised provinces, CHIME dating, geometallurgy
Dr Stuart Bull, BSc Hons, PhD (Monash)	Clastic and carbonate sedimentology and volcanology
Dr Isabelle Chambefort, MSc (Clermont-Ferrand), PhD (U Geneva)	Petrology
Dr Zhaoshan Chang, BSc (PKU), PhD (PKU, WSU)	Skarn, porphyry and epithermal deposits; LA-ICPMS zircon dating
Dr Huayong Chen, BSc, MSc (PKU), PhD (Queen's)	IOCG, porphyry and epithermal deposits
Professor David Cooke, BSc Hons (Latrobe), PhD (Monash)	Fluid-rock geochemistry, porphyry Cu-Au
Professor Tony Crawford, BSc Hons, PhD (Melbourne)	Petrology, geochemistry and tectonics of volcanic arcs
Professor Leonid Danyushevsky, PhD (Vernadsky Inst.)	Petrology, geochemistry, application of melt inclusions
Dr Garry Davidson, BSc Hons (ANU), PhD (UTAS)	Sulfur isotope geochemistry and Cu-Au ores
Dr Paul Davidson, BSc Hons, PhD (UTAS)	Melt and fluid inclusions
Dr Trevor Falloon, BSc Hons (Canterbury), BTeaching, PhD (UTAS)	Marine geoscience, petrology
Dr Sandrin Feig, MSc, PhD (Hannover)	Petrology
Associate Professor Jeff Foster, BSc Hons (City), MSc (Leicester)	Magmatic ore deposits
Dr Marcel Guillong, PhD (ETH Zurich)	Laser analytical techniques
Dr Jacqueline Halpin, BSc Hons (Melbourne), PhD (Sydney)	Metamorphic petrology, geochronology
Dr Anthony Harris, BSc Hons, PhD (UQ)	Ore deposit geology/geochemistry
Dr Julie Hunt, MSc (UBC), PhD (JCU)	Geometallurgy, IOCG deposits
Dr Dave Hutchinson, HND (Camborne, Sch of Mines), BSc Hons, PhD (Cardiff)	Ni-Cu/PGE mineralisation
Dr Emily Johnson, BSc (Michigan), PhD (Oregon)	Petrology, physical volcanology
Deputy Director, Professor J Bruce Gemmell, BSc (UBC), MA, PhD (Dartmouth)	VHMS deposits and epithermal Au-Ag
Dr Maya Kamenetsky, PhD (UTAS)	MLA-SEM, geometallurgy, petrology
Professor Vadim Kamenetsky, BSc Hons (Moscow), PhD (Vernadsky Inst.)	Petrology and geochemistry of melt inclusions
Associate Professor Khin Zaw, BSc (Rangoon), MSc (Queen's), PhD (UTAS)	Fluid inclusions, SE Asian metallogenesis
Dr Lyudmyla Koziy, PhD (UTAS)	Fluid flow modelling
Dr Peter McGoldrick, BSc Hons, PhD (Melbourne)	Geochemistry of ore deposits and their halos
Dr Andrew McNeill, BSc Hons, PhD (UTAS)	Petrology, VHMS deposits, mineral exploration
Professor Jocelyn McPhie, BA Hons (Macquarie), PhD (UNE)	Volcanic facies architecture and volcanic textures
Dr Sebastien Meffre, BSc Hons, PhD (Sydney)	Petrology and tectonics of the SW Pacific
Dr Steve Micklethwaite, BSc, PhD (Leeds)	Structural geology
Dr Janina Micko, MSc (Birmingham), PhD (UBC)	Geology and genesis of hydrothermal ore deposits
Dr Karin Orth, BSc Hons (Monash), PhD (UTAS)	Volcanology
Dr Anya Reading, BSc Hons (Edinburgh), PhD (Leeds)	Geophysics, seismology, computational methods
Dr Michael Roach, BSc Hons (Newcastle), PhD (UTAS)	Geophysical responses of ore deposits
Dr Ralf Schaa, MSc (Cologne), PhD (UTAS)	Remote sensing, approximate modelling and inversion of TEM
Dr Rob Scott, BSc Hons, PhD (Monash)	Structural geology, gold deposits
Dr David Selley, BSc Hons (Adelaide), PhD (UTAS)	Structural geology/basin analysis, sedimentary Cu
Dr Helen Thomas, MSc (Leicester), PhD (Manchester)	Geochemistry, geochronology
Professor Steve Walters, BSc Hons, PhD (Sheffield)	Geometallurgy, applied mineralogy, exploration technologies
Dr Tony Webster, BSc Hons (Latrobe), BA (UNE), MSc (JCU), PhD (UTAS)	MTEC Senior Lecturer and Masters Program Coordinator
Professor Jamie Wilkinson, BA Hons (Cambridge), PhD (Southampton)	Geochemistry and isotopes of ore fluids

ACADEMIC/RESEARCH STAFF BASED AT COLLABORATIVE INSTITUTIONS

Dr Stacey Borg	CSIRO Exploration & Mining
Professor Dee Bradshaw	JKMRC, University of Queensland
Professor Alan Bye	WH Bryan Mining Geology Research Centre, University of Queensland
Professor Stephen Cox	Node Leader: Australian National University
Professor Grant Garven	TUFTS
Dr Louisa Groves	JKMRC, University of Queensland
Dr Angela Halfpenny	Australian National University
Associate Professor Jeff Hedenquist	Colorado School of Mines
Associate Professor Janet Hergt	Node Leader: University of Melbourne
Professor Murray Hitzman	Colorado School of Mines
Dr Luke Keeney	JKMRC, University of Queensland
Dr Jamie Laird	CSIRO Exploration & Mining
Dr Weihua Liu	CSIRO Exploration & Mining
Dr Roland Maas	University of Melbourne
Dr Angus McFarlane	JKMRC, University of Queensland
Dr Simon Michaux	JKMRC, University of Queensland
Dr Khoi Ke Nguyen	JKMRC, University of Queensland
Dr Italo Onederra	WH Bryan Mining Geology Research Centre, University of Queensland
Dr Bence Paul	University of Melbourne
Dr Chris Ryan	Node Leader: CSIRO Exploration & Mining
Mr Patrick Walters	JKMRC, University of Queensland
Professor Steve Walters	JKMRC, University of Queensland

TECHNICAL/ADMINISTRATIVE STAFF

Mr Chris Allen	Geophysics Laboratory Technician
Dr Kate Bromfield	Research Assistant
Mr Steve Calladine	Communications Manager
Mrs Michele Chapple-Smith	Lapidary Technician
Mr Peter Cornish	Laboratory Manager
Mr Alex Cuison	Lapidary Technician
Ms Grace Cumming	Research Assistant
Ms Sarah Gilbert, BSc Hons (UTAS)	Senior Technician ICP-MS
Ms Christine Higgins, Grad.Cert. Management (UTAS)	Finance Manager
Mrs Nilar Hlaing, BSc (Rangoon)	Personal Assistant to the Director
Mr Shaun Inglis	Research Technician
Dr Roman Leslie	Research Assistant
Mr Ian Little	Laboratory Analyst
Mrs Katie McGoldrick	Laboratory Assistant
Mrs Karen Mollross	Finance Officer
Ms Caroline Mordaunt, BA Hons (King's College London)	Administrative Assistant
Mr Ross Olsen	Geophysics Laboratory Technician
Ms June Pongratz	Publications and Media Resource Centre Manager
Mr Phil Robinson, BSc Hons (Nottingham)	Analytical Services Manager
Miss Helen Scott, BSc Hons (UTAS), BEd (QUT)	Finance Officer
Ms Isabella von Lichtan, BSc Hons (UTAS)	Curator/ MTEC Administrative Assistant
Mr Andy Wakefield	Geophysics Technician

ADVISORY BOARD

Chair: John Dow	Consultant	Alan Goode	AMIRA International
Paul Agnew	Rio Tinto	Janet Hergt	University of Melbourne
Trevor Beardsmore	Barrick Gold	John Holliday	Newcrest Mining
Margaret Britz	UTAS	Ross Large	CODES
Tony Brown	Mineral Resources Tasmania	Jocelyn McPhie	CODES
Alan Canty	UTAS	Ian Sandl	Teck
Graham Carr	CSIRO Exploration and Mining	Donna Sewell	AngloGold Ashanti
Dean Collett	Newcrest Mining	Steve Turner	Newmont Exploration
Stephen Cox	Australian National University	Steve Walters	CODES/JKMRC
Lynda Daley	Newmont Asia Pacific	Noel White	Consultant
Kathy Ehrig	BHP Billiton	Jamie Wilkinson	Imperial College London
Bruce Gemmell	CODES	Ian Willis	Anglo American

EXECUTIVE COMMITTEE

Chair: Ross Large	Director, CODES	Christine Higgins	Finance Manager
Steve Calladine	Communications Manager	Nilar Hlaing	Personal Assistant to the Director
David Cooke	Formation (2) Program Leader	Andrew McNeill*	Discovery (3) Program Leader (new Leader)
Tony Crawford	Location (1) Program Leader	Jocelyn McPhie	Co-ordinator Graduate Research
Leonid Danyushevsky	Technology (5) Program Leader	June Pongratz*	Publications and Media Resource Centre Manager
Jeff Foster	Recovery (4) Program Leader	Steve Walters*	Recovery (4) Program Leader (part of year)
Bruce Gemmell	Deputy Director, CODES	*Committee members for part of the year.	

SCIENCE PLANNING PANEL

(ALSO INCLUDES THE EXECUTIVE COMMITTEE AND ALL CODES' RESEARCH STAFF AND STUDENTS)

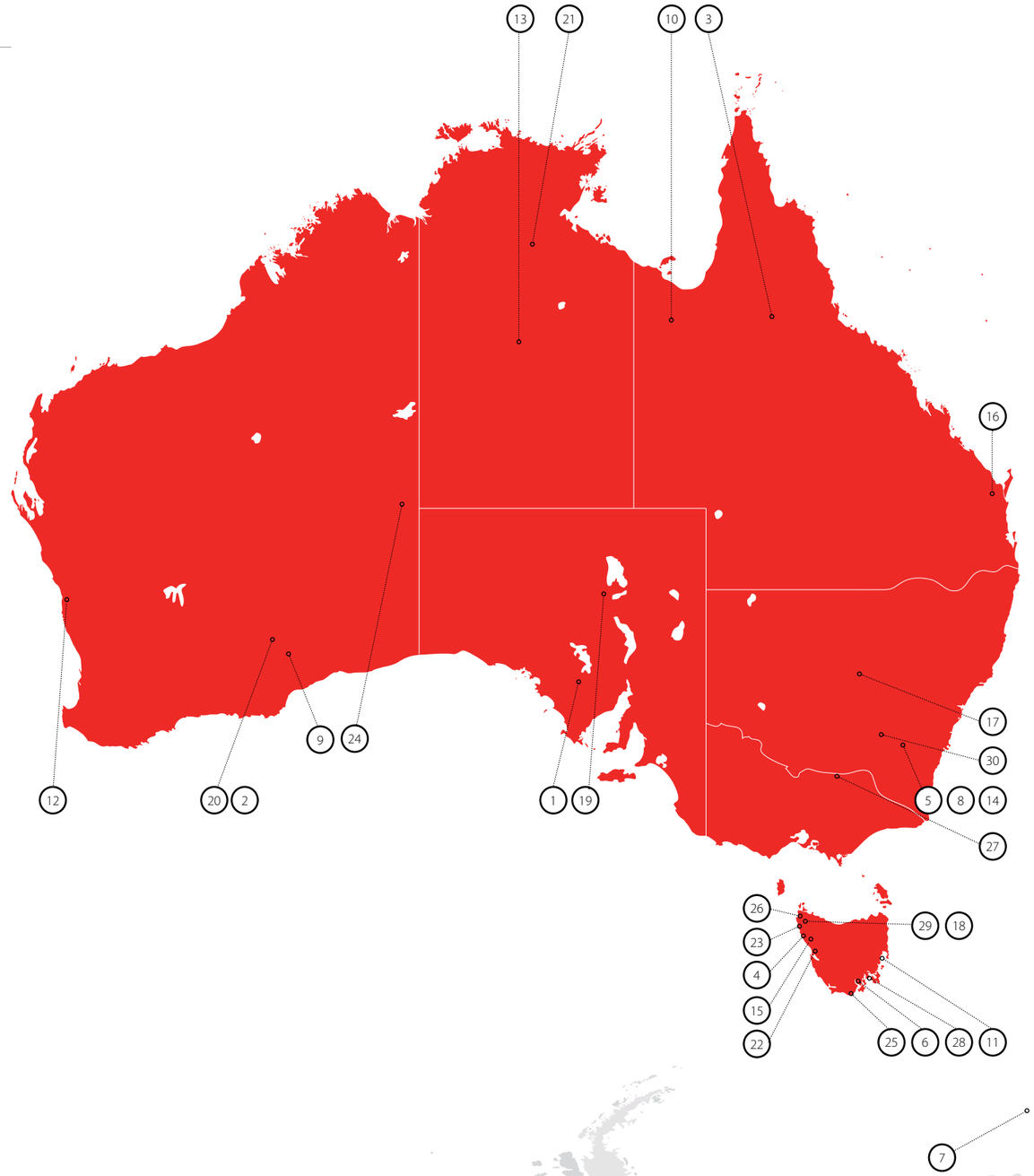
Chair: Ross Large	Director, CODES	Geoff Green	Mineral Resources Tasmania
Stacey Borg	CSIRO Exploration and Mining	Angela Halfpenny	Australian National University
Tony Brown	Mineral Resources Tasmania	Paul Heithersay	PIRSA
Graham Carr	CSIRO Exploration and Mining	Janet Hergt	University of Melbourne
Dean Collett	Newcrest Mining	Neil Hughes	MMG
Stephen Cox	Australian National University	Jamie Laird	CSIRO Exploration and Mining
Lynda Daley	Newmont Asia Pacific	Marcelo Marquez	National University of Patagonia
Kim Denwer	Bass Metals	Bence Paul	University of Melbourne
Cathy Dickins	St Barbara	Lee Sampson	Barrick Gold
John Dow	Consultant	Noel White	Consultant
Kathy Ehrig	BHP Billiton	Ian Willis	Anglo American
Alan Goode	AMIRA International	Jon Woodhead	University of Melbourne
David Green	Mineral Resources Tasmania		

STUDENT PROJECTS

In Australia /

Project locations are shown in capitals. Unless marked otherwise, student projects shown here are field and lab-based PhD projects.

1. **Agangi, Andrea**. SA
   Magmatic and volcanic evolution of giant intraplate felsic igneous provinces: Gawler Range Volcanics and Hiltaba Suite, South Australia.
2. **Belford, Susan.** WA
   Genetic and chemical characterisation of the Archaean Jaguar VHMS deposit.
3. **Best, Fiona.** QLD
   The petrogenesis of the Dido Tonalite, northern Queensland.
4. **Braniff, Victoria.** TAS
   The structure and deformational history of the Savage River magnetite ore bodies, NW Tasmania.
5. **Cuison, Ana Liza.** NSW
   Geology and genesis of the Ridgeway porphyry Au-Cu deposit, NSW.
6. **Donaldson, Paul.** TAS (Hons)
   Facies architecture and radar stratigraphy of the Seven Mile Spit, Tasmania.
7. **Ferguson, Paul.** TAS (Masters)
   Origins of large negative anomalies in oceanic crust, Macquarie Island.
8. **Fox, Nathan.** NSW
   Controls on alteration and mineralisation in the Cadia East Au-Cu porphyry copper deposit, NSW.
9. **Gregory, Daniel.** WA
   Pyrite Black Shales: a source of gold for orogenic gold deposits, St Ives district, W Kambalda, WA.
10. **Guilliamse, Josh.** QLD (Hons)
    Early Mesoproterozoic microbial vent communities from the Century deposit, NW Queensland
11. **Hey, Ben.** TAS (Hons)
    A geophysical reconnaissance of archaeological sites on Maria Island, Tasmania.
12. **Jervis-Bardy, Nicholas.** WA (Hons)
    Geophysical investigation of Eneabba geothermal prospect, WA.
13. **Johns, Hamish.** NT (Hons)
    Characterisation of the Northern Star uranium mineralisation, Northern Territory, with special emphasis on IOCG relationships.



14. **Keeney, Luke.** NSW [JKMRC]
Integrated geometallurgical modelling of the Cadia East deposit.

15. **Knight, Kyen.** TAS (Hons)
Geophysical characterisation of Rosebery ore body and host environment.

16. **Kor, Ting.** QLD (Hons)
Hydrothermal breccias at the Coalstoun porphyry Cu-Au-Mo deposit, SE Queensland.

17. **Kyne, Roisin.** NSW
Structural controls on mineralisation, including sulfide mineralogy, at the CSA mine, Cobar NSW.

18. **Lygin, Alexey.** TAS
The geology, geochemistry and genesis of the Avebury Ni deposit, Tasmania.

19. **Mackay, Wallace.** SA
Sedimentology and structure of the Curdimurka Subgroup, Willouran Range, South Australia.

20. **Macklin, Daniel.** WA (Hons)
Alteration at the Teutonic Bore (VHMS) deposit Western Australia.

21. **Maier, Rodney.** NT
Pyrite trace element halos to northern Australian SEDEX deposits.

22. **Pereira da Fonseca, Pedro.** TAS
Strato-tectonic setting of massive sulfide deposits: Mount Read Volcanics (western Tasmania) and the Iberian Pyrite Belt (Portugal).

23. **Sargent, Brendan.** TAS (Hons)
Geophysical characterisation of the Roaring 41 South Prospect, Balfour.

24. **Staubmann, Markus.** WA (Hons)
The petrogenesis and economic potential of the Southern Cavenagh Range Intrusion (west Musgraves), Western Australia.

25. **Stubley, Tim.** TAS (Hons)
The structure and stratigraphy of the Ironbound Group, Southwest Tasmania.

26. **Tomlin, Michael.** TAS (Hons)
Optimised gravity survey design.

27. **Webb, Katherine.** VIC (Hons)
The Boorhaman intrusive complex, Victoria - geology, geochemistry, geochronology.

28. **Whitfield, Allison.** TAS (Hons)
Sedimentology and detrital zircon geochronology of the Permo-Triassic transition in the northern Tasman Peninsula, Tasmania.

29. **Wu, Selina.** TAS
Volcanic hosted massive sulfide deposits of the Que-Hellyer Volcanics, western Tasmania.

30. **Zukowski, Wojciech.** NSW
Geology and mineralisation of the Endeavour 41 gold deposit, Cowal District, NSW.

Lab-Based Projects – Single or Multi-Sites /

Bonnici, Natalee
The mineralogical and textural characteristics of Cu-Au deposits related to mineral processing attributes.

Bychkov, Kirill
Numerical modelling of sulfide precipitation from mafic magmas with implications for the formation of layered intrusions.

Chauhan, Mitesh [JKMRC]
Application of small scale flotation testing.

Cracknell, Matthew
Innovative data inference from spatial datasets in earth science.

Evans, Cathy [JKMRC]
The relationship between mineral characteristics of ores and the variation in their processing attributes.

Gilbert, Sarah
Development of analytical methods and standard reference materials for determination of trace element concentrations and isotopic ratios in sulfur-rich minerals and silicate glasses.

Hoschke, Terence (Masters)
Geophysical signatures of gold-copper porphyry systems.

Leigh, George [JKMRC]
Multi-resolution image analysis for process mineralogy.

McMahon, Claire
Controls on the major and trace elements content of pyrite in hydrothermal alteration envelopes.

Paleri, Siddarth [UMelb]
Spatial systematics of copper isotope fractionation in the Rainbow hydrothermal vent field, 36°14'N, Mid-Atlantic Ridge.

Parbhakar-Fox, Anita
Texture-based approaches to predictive geo-environmental modelling.

Parra Galvez, Hector Ivan [BRC]
Quantifying the impact of blast induced fragment conditioning on leaching performance.

Pieterson, Kevin [JKMRC]
Geological and geometallurgical texture discrimination.

Schaa, Ralf
Rapid approximate 3D inversion of transient electromagnetic data.

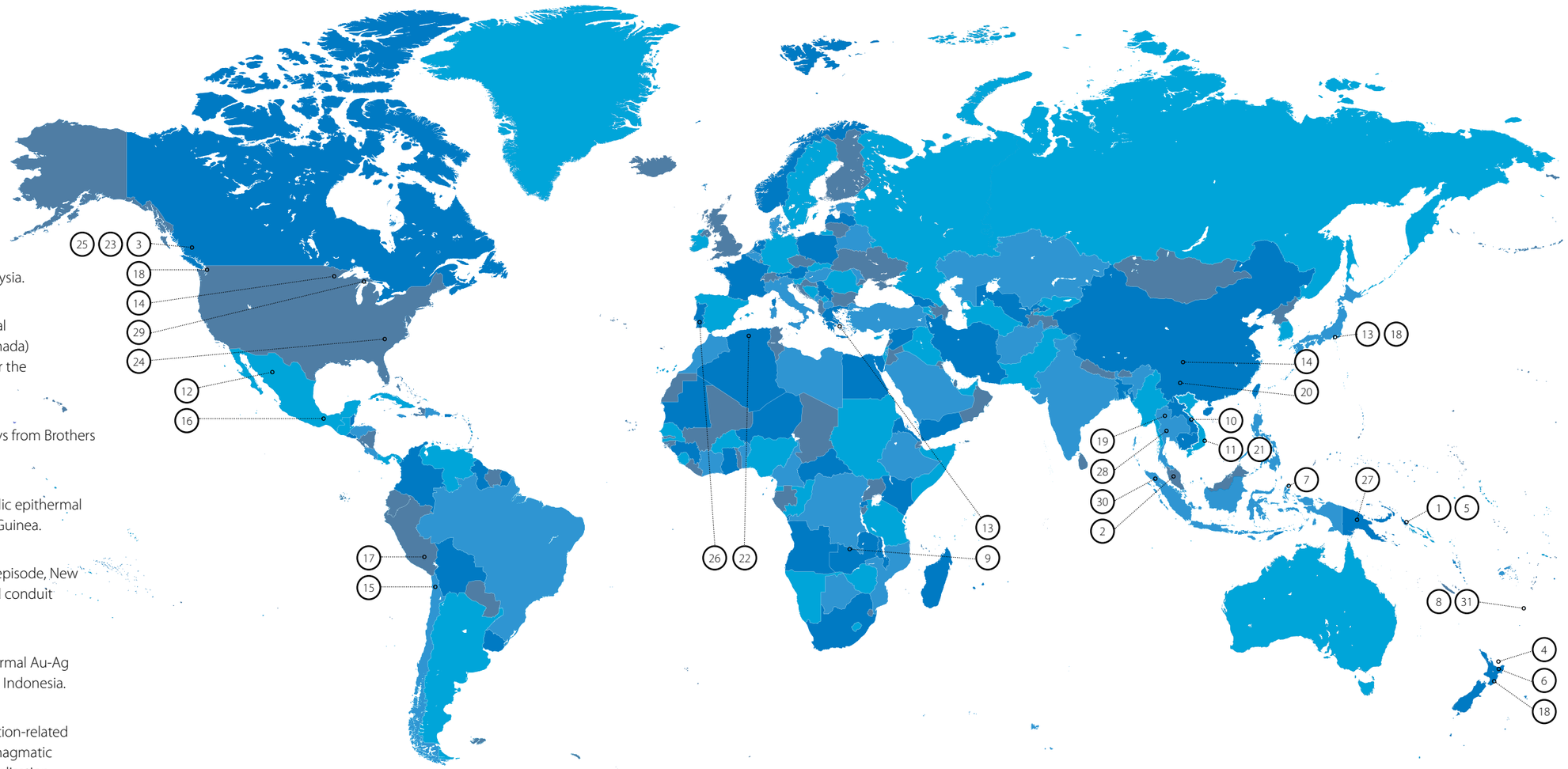
Singoyi, Blackwell
Controls on the geochemistry of magnetite in hydrothermal fluids.

Vasyukova, Olga
The origin of quartz and fluid inclusions in mineralised porphyries.

Vatandoost Kohnehshahri, Adel
Automated petrophysical characterisation of drill core as a link to mineral processing attributes.

Outside Australia /

Project locations are shown in capitals.
Unless marked otherwise, student projects shown here are PhDs.



1. **Ageneau, Mathieu.** PAPUA NEW GUINEA
   Geology of the Kapit ore zone and comparative geochemistry with the Minifie and Lienetz ore zones, Ladolam gold deposit, Lihir Island, Papua New Guinea.
2. **Basori, Mohd Basril Iswadi Bin.** MALAYSIA
   Geology of volcanic hosted massive sulfide (VHMS) deposits in Central Belt, Peninsular Malaysia.
3. **Bath, Adam.** CANADA
   The geochemistry of melt inclusions and mineral phases from the Mount Polley and Lorraine (Canada) alkalic Cu-Au porphyry deposits: implications for the formation of ore deposits.
4. **Berkenbosch, Heidi.** NEW ZEALAND
   Geochemistry of hydrothermal mineral chimneys from Brothers volcano, Kermadec arc.
5. **Blackwell, Jacqueline.** PAPUA NEW GUINEA
   Characteristics and origins of breccias in an alkalic epithermal gold deposit: Ladolam, Lihir Island, Papua New Guinea.
6. **Brown, Emma.** NEW ZEALAND (Hons)
   Pumice vesicles of the 15.8ka Rotorua eruptive episode, New Zealand: Implications for eruptive dynamics and conduit processes.
7. **Clark, Lindsey.** INDONESIA
   The geology and genesis of the Kencana epithermal Au-Ag deposit, Gosowong goldfield, Halmahera Island, Indonesia.
8. **Cobenas Benites, Gisela.** SW PACIFIC
   Metal and volatile contents of primitive subduction-related magmas (Hunter Ridge, SW Pacific): Assessing magmatic contributions to volcanic-hosted seafloor mineralisation.
9. **Croaker, Mawson.** ZAMBIA
   Geology and genesis of the Nkana copper deposit, Zambia.
10. **Cromie, Paul.** LAOS PDR
    Geological setting, geochemistry and genesis of the Sepon Mineral District, Laos PDR.
11. **Dinh, Quang Sang.** VIETNAM
    Geochronology and geological evolution of the northern margin of the Kontum massif, central Vietnam.
12. **Galvan Gutierrez, Victor Hugo.** MEXICO
    Palmarejo carbonate base-metals silver-gold epithermal deposit, Trogan Project, Chihuahua, Mexico.
13. **Gordee, Sarah.** GREECE, JAPAN
    Characteristics of submarine volcanic facies in oceanic arc depocentres.
14. **Guan, JianXiang.** CHINA, USA
    Origin of associated magnetite and sulfide mineralisation in large gabbroic intrusions: A LA-ICP-MS study of minerals and melt inclusions from the Panzhihua and Taihe intrusions in Emeishan LIP and Duluth Complex.
15. **Ireland, Timothy.** CHILE
    Geological framework of porphyry and epithermal mineralisation in the Collahuasi district, Tarapacá, Chile.
16. **Jansen, Nicholas.** MEXICO
    Geology and geochemistry of the Ixhuatan lithocap, and its relationships to porphyry and epithermal mineralisation.
17. **Jones, Benjamin.** PERU
    Tectonic setting and magmatic evolution of the Antapaccay porphyry copper-gold and skarn deposit, Peru.
18. **Jutzeler, Martin.** NEW ZEALAND, JAPAN, USA
    Behaviour of submerged eruption plumes using data from facies analysis of a variety of submarine pyroclastic successions.
19. **Kamvong, Teera.** THAILAND, LAOS PDR
    Geology and genesis of porphyry-skarn Cu-Au deposits at the northern Loei Fold Belt, Northeast Thailand and Laos.
20. **Lai, Chun Kit.** CHINA
    Tectonics and metallogenesis of ophiolites and volcanics in southwestern Yunnan, China.
21. **Manaka, Takayuki.** VIETNAM
    Geology and mineralisation characteristics of the Phuoc Son goldfields, central Vietnam.
22. **McGee, Brendan.** ALGERIA
    The geology and mineralisation of the Tala Hamza Pb-Zn deposit, Algeria.
23. **Micko, Janina.** CANADA [MDRU]
    The gology and genesis of the Central Zone alkali copper-gold porphyry deposit, Galore Creek district, northwestern British Columbia, Canada.
24. **Moye Jr, Robert Josephus.** USA
    Genesis and chemical and kinematic evolution of the late Proterozoic Ridgeway gold deposit in the Carolina Terrane of the central South Carolina piedmont, USA.
25. **Pass, Heidi.** CANADA
    Breccia-hosted chemical and mineralogical zonation patterns of the Northeast Zone. Mt Polley Cu-Au-Ag alkalic porphyry deposit, British Columbia, Canada.
26. **Pereira da Fonseca, Pedro.** PORTUGAL
    Strato-tectonic setting of massive sulfide deposits: Mount Read Volcanics (western Tasmania) and the Iberian Pyrite Belt (Portugal).
27. **Rinne, Marc.** PAPUA NEW GUINEA
    Characteristics and relationships of the contrasting Wafi-Golpu Cu-Au porphyry- epithermal system, Papua New Guinea.
28. **Salam, Abhisit.** THAILAND
    Geology and genesis of the Chatree deposits, Phetchabun Province, central Thailand.
29. **Steadman, Jeffrey.** USA, CANADA
    The source of Au in banded iron formation (BIF) - hosted gold deposits.
30. **Sutopo, Bronto.** INDONESIA
    The Martabe Au-Ag high-sulfidation epithermal mineralisation in the Tapanuli Selatan district, North Sumatra Province, Indonesia: Implications for ore genesis and exploration.
31. **Tetroeva, Sofia.** SW PACIFIC
    Petrology and geochemistry of adakites and related rocks from the Hunter Ridge, Southwest Pacific.

Program One /

LOCATION

Objective /

To better understand the links between tectonic setting, magmatism, basin evolution and ore deposit formation in modern and ancient settings.

Introduction /

The Location Program hosts the majority of fundamental research being carried out in CODES, with a strong emphasis on magmatic petrology and geochemistry, tectonics, and volcanology. Researchers within this program work across the scales from microscopic to mountain belt, and from laboratory- to field-based studies, attempting to better understand the major controls on the location, timing and size of key ore deposits, particularly those in arc-backarc settings and in continental rift basins. Current projects cover a diverse range of themes, from fundamental to more strategic in nature, and team members with a more fundamental science background are strongly encouraged to become involved in at least one industry- or mineralisation-related project.

Highlights /

» Successful completion of Project P1A4: Ore Deposits of SE Asia, including meetings in Chiang Mai (Thailand) and Hobart.

» Successful completion of the Olympic Dam P1B1 project, which was being conducted in collaboration with BHP Billiton. A follow-up project has commenced.

» Research outcomes in P1B1 led to the first public presentations of a challenging new model for the Olympic Dam Cu-Au-U-REE deposit – one of the world's largest ore deposits.

» Successful completion of project P1B2 (AMIRA project P962): Ni-PGE potential of mafic and ultramafic magmas – a combined melt inclusions and numerical modelling approach.

» Jacqui Halpin awarded one of only two UTAS Research Excellence Awards presented to Early Career Researchers.

Leader /
Tony Crawford

Team Members /
Sharon Allen, Mike Baker, Ron Berry, Stuart Bull, Isabelle Chambefort, Grace Cumming, Leonid Danyushevsky, Paul Davidson, Trevor Falloon, Sandrin Feig, Karsten Goemann, Jacqueline Halpin, Emily Johnson, Vadim Kamenetsky, Maya Kamenetsky, Ross Large, Roman Leslie, Roland Maas, Charles Makoundi, Peter McGoldrick, Andrew McNeill, Jocelyn McPhie, Sebastien Meffre, Anya Reading, Phil Robinson, Chris Ryan, Khin Zaw

Phd Students /
Andrea Agangi, Mohd Basril Iswadi Bin Basori, Fiona Best, Kirill Bychkov, Gisela Cobenas, Paul Cromie, Quang Sang Dinh, Pedro Fonseca, Hugo Galvan, Sarah Gordee, JianXiyang Guan, Martin Jutzeler, Teera Kamvong, Chun Kit Lai, Rodney Maier, Takayuki Manaka, Abhisit Salam, Sofia Tetroeva, Olga Vasyukova

Masters Students /
Glen Diemar, You Jin Lee.

Honours Students /
Emma Brown, Josh Guilliamse, Markus Staubmann, Tim Stubley

Collaborators /
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ANGLO AMERICAN EXPLORATION – Paul Polito, Tony Donaghy, Allan Kneeshaw
AUSTRALIAN MUSEUM – Lin Sutherland
AUSTRALIAN NATIONAL UNIVERSITY – Richard Arculus, Hugh O'Neill, Marc Norman, Greg Yaxley
BEADELL RESOURCES – Rob Watkins
BHP BILLITON – Kathy Ehrig, Nick Green
CARDIFF UNIVERSITY, UK – Andrew Kerr
CHIANG MAI UNIVERSITY, THAILAND – Weerapan Srichan, Phisit Limtrakun, Yuenyong Panjasawatwong, Sampan Singharajwarapan
CHINESE ACADEMY OF GEOLOGICAL SCIENCE, CHINA – Zengqian Hou
COLORADO STATE UNIVERSITY, USA – Holly Stein
DEPARTMENT OF MINERAL RESOURCES, THAILAND – Somboon Khositanont, Pol Chaodumrong
FROGTECH – Nick Direen
GEOLOGICAL SURVEY OF NSW – Barney Stevens
GEOLOGICAL SURVEY OF QUEENSLAND – Ian Withnall
GEOSCIENCE AUSTRALIA – Terry Mernagh, David Huston
GEOSCIENCE BC – Kirstie Simpson
GFZ GERMAN RESEARCH CENTRE FOR GEOSCIENCES, GERMANY – Rainer Thomas
HANOI UNIVERSITY OF GEOLOGY AND MINING, VIETNAM – Hai Thanh Tran
IFM-GEOMAR, GERMANY – Armin Freundt
IMPERIAL COLLEGE LONDON – Andrew Berry
INSTITUTE FOR FRONTIER RESEARCH ON EARTH EVOLUTION, JAPAN – Yoshihiko Tamura
INSTITUTE OF EARTH SCIENCES-ACADEMIA SINICA, TAIWAN – Georg Zellmer
INSTITUTE OF EXPERIMENTAL MINERALOGY, RUSSIA – Eduard Konnikov, Oleg Safonov
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INSTITUTE OF OCEANOGRAPHY, UK – Mike Coffin
JAMES COOK UNIVERSITY – Bob Henderson
KUNMING UNIVERSITY OF SCIENCE AND TECHNOLOGY, CHINA – Chuan Dong Xue
LAURIN TECHNIC – Michael Shelley
MACQUARIE UNIVERSITY – Norm Pearson, Elena Belousova
MONASH UNIVERSITY – Reid Keays, Masssimo Raveggi
MOSCOW STATE UNIVERSITY, RUSSIA – Pavel Plechov
MURORAN UNIVERSITY, JAPAN – Yoshi Goto
NATIONAL LABORATORY OF ENERGY AND GEOLOGY, PORTUGAL – Carlos Rosa
NIIGATA UNIVERSITY, JAPAN – Katsuki Kurokawa
PRIMARY INDUSTRIES AND RESOURCES SOUTH AUSTRALIA – Martin Fairclough
SIRIUS RESOURCES – Tim Craske, Mark Bennett
SMITHSONIAN INSTITUTION, USA – Richard Fiske
STATE KEY LABORATORY IN ORE DEPOSIT GEOCHEMISTRY, CHINA – Xieyan Song, Ruizhong Hu, Bi Xianwu
UNITED STATES GEOLOGICAL SURVEY – Poul Emsbo
UNIVERSIDAD NACIONAL DE LA PATAGONIA, ARGENTINA – Marcelo Marquez
UNIVERSITI KEBANGSAAN MALAYSIA – Wan Faud Wan Hassan, Mohd Rozi Umor
UNIVERSITY COLLEGE OF SCIENCE, SCHOOL OF GEOLOGY, IRAN – Mirsaleh Mirmohammadi
UNIVERSITY OF BERN, SWITZERLAND – Thomas Pettke
UNIVERSITY OF CALIFORNIA BERKELEY, USA – Rebecca Carey
UNIVERSITY OF CALIFORNIA RIVERSIDE, USA – Tim Lyons
UNIVERSITY OF CENTRAL MISSOURI, USA – John Nold, Mark Dudley
UNIVERSITY OF FLORIDA AT GAINESVILLE, USA – Mike Perfit
UNIVERSITY OF LISBON, PORTUGAL – Jorge Relvas
UNIVERSITY OF MALAYA – Azman Ghandi, Teh Guan Hoe
UNIVERSITY OF MELBOURNE – Jon Woodhead
UNIVERSITY OF NAPLES, ITALY – Benedetto De Vivo
UNIVERSITY OF NSW – Ian Graham
UNIVERSITY OF OREGON, USA – Kathy Cashman, Ilya Bindeman, Paul Wallace
UNIVERSITY OF QUEENSLAND – Sue Golding, Paulo Vasconcelos, Ben Cohen
UNIVERSITY OF SCIENCE & TECHNOLOGY, CHINA – Yuling Xie
UNIVERSITY OF TASMANIA – Donna Satterthwait
UNIVERSITY OF THE WITWATERSRAND, SOUTH AFRICA – Allan Wilson
UNIVERSITY OF WESTERN AUSTRALIA – Mark Barley
UNIVERSITY OF WOLLONGONG – Chris Fergusson
VERNADSKY INSTITUTE, RUSSIA – Alexey Ariskin, Galina Barmina
VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY, USA – Robert Bodnar
WOODS HOLE OCEANOGRAPHIC INSTITUTION, USA – Andrey Gurenko

Core Projects /

Theme 1A – Geodynamic Controls on the Fertility of Foldbelts, Cratons and Sedimentary Basins

P1A1 Palaeoproterozoic magmatism and mineralisation

P1A2 Mafic magmatism in modern submarine SW Pacific settings

P1A3 Global ocean chemistry, marine basins and mineralisation

P1A4 Ore deposits of SE Asia

P1A6 Tectonic significance and mineralisation potential of volcano-plutonic belts and ophiolites at the northern end of the Tasman Line, N Queensland

Theme 1B – Magmas, Volatiles and Metals

P1B1 Felsic magmas in volcanic arcs and intraplate volcanic provinces – eruption style, degassing processes, fluid evolution and links to mineralisation

P1B2 Ni-PGE potential of mafic and ultramafic magmas – a combined melt inclusions and numerical modelling approach (AMIRA P962)

P1B3B Melt-melt immiscibility and the origin of magnetite-apatite deposits

THE ABOVE LIST REPRESENTS ACTIVE PROJECTS IN 2010

Project Summaries /

P1A1
PALAEOPROTEROZOIC MAGMATISM AND MINERALISATION

Leader /
Tony Crawford

Team Members /
Mike Baker, Roland Maas

Collaborators /
Reid Keays, Barney Stevens, Ian Withnall

A paper in *Precambrian Research* was published in 2010, recording Mike Baker's PhD study of the Palaeoproterozoic mafic magmas in the Georgetown Block, N Queensland, and comparing these with similar-aged mafic rocks from the Broken Hill Block.

Two sub-projects on the Broken Hill Palaeoproterozoic mafic rocks are on-going:

» In collaboration with Reid Keays from Monash University, the study of the PGE distribution in the regional- and line-of-lode mafic sills in the Broken Hill Block is underway, characterising the nature of the mantle source and controls on sulfide saturation in these rocks.

» Detailed across-sill geochemical profiling is in progress to elucidate the way-up for the host sequences of the Broken Hill ore lenses. This is being done in collaboration with Barney Stevens (GS-NSW).

P1A2
MAFIC MAGMATISM IN MODERN SUBMARINE SW PACIFIC SETTINGS

Leader /
Leonid Danyushevsky

Team Members /
Tony Crawford, Trevor Falloon

Student /
Gisela Cobenas

Collaborators /
Andrew Berry, Robert Bodnar, Benedetto De Vivo, Hugh O'Neill, Pavel Plechov, Jon Woodhead

This project aims at improving the understanding of magma generation and evolution processes in the complex region of convergent plate margins in the Southwest Pacific; focusing largely on the Hunter Ridge, a submarine bathymetric high that extends between the southern Vanuatu arc and Fiji.

Activities in 2010 included:

» Over 120 samples of volcanic and plutonic rocks collected in 2009 along the entire length of the Hunter Ridge have been crushed, milled and submitted for major and trace element analysis by XRF and solution ICP-MS. The full results are expected in the first half of 2011.

» Zircons from plutonic rocks dredged from the central parts of the Hunter Ridge have been dated at CODES by LA-ICP-MS, yielding ages of 10 and 5 Ma, corresponding to the age of the substrate and rifting, respectively. This first information on the age of the substrate, now proven to be a deformed block of old arc crust from the proto-Vitiaz arc, has important implications for the geodynamic reconstructions of this region of the SW Pacific.

» PhD student, Gisela Cobenas, began to analyse major and trace element compositions (including base metals) of phenocrysts (olivine, plagioclase, clinopyroxene, orthopyroxene, amphibole) from a number of volcanic series from the Hunter Ridge. The aim is to understand the behaviour of base metals during evolution of arc magmas.

» In collaboration with Hugh O'Neill and Andrew Berry, the oxidation state of Fe in a range of BABB glasses was determined, using the Beamline I18 at the Diamond Light Source Synchrotron in the UK. Preliminary results indicate a significantly more oxidised nature of BABB and arc magmas. This has important implications for determining the compositions and generation conditions of subduction-related parental melts, and for interpretation of data obtained from studies of melt inclusions in phenocrysts.

» In collaboration with Benedetto De Vivo and Robert Bodnar, a study of melt inclusions in olivine phenocrysts from modern volcanic rock in southern Italy has revealed the importance of polybaric crystallisation during explosive eruption. A paper has been submitted for publication in the *Journal of Petrology*.

P1A3
GLOBAL OCEAN CHEMISTRY, MARINE BASINS AND MINERALISATION

Leader /
Peter McGoldrick

Students /
Josh Guilliamse, Rodney Maier

Collaborators /
Tim Lyons, Donna Satterthwait

The aims are to decipher processes that controlled the sulfur chemistry and redox state of oceans that existed in northern Australia approximately 1.65 billion years ago, understand how coeval ocean water interacted with hydrothermal fluids responsible for forming the giant northern Australian Proterozoic SEDEX Zn-Pb-Ag deposits, and elucidate the role played by (micro-) organisms during seafloor venting of fluids responsible for forming Proterozoic sedimentary Zn mineralisation.

» International collaborator, Tim Lyons, spent four months at CODES supported by a UTAS Visiting Fellowship. He contributed to a paper entitled 'Widespread ferruginous conditions in mid-Proterozoic oceans', which has been submitted to *Science*. This paper presents Fe speciation data from a suite of mid-Proterozoic marine mudstones, including a large number from the McArthur and Mt Isa Basins. The results indicate that ferruginous (anoxic and Fe^{2+}-rich) conditions were both spatially and temporally extensive across diverse paleogeographic settings in the mid-Proterozoic ocean, inviting new views on the temporal distribution of iron formations, the availability of bio-essential trace elements, and the formation of primary geochemical dispersions around ancient submarine hydrothermal vents.

» Peter McGoldrick presented an invited keynote talk at the SEG meeting in Keystone, USA, during October. This talk was published as a peer-reviewed contribution to the conference volume.

» Rodney Maier's PhD thesis – 'Pyrite trace element halos to northern Australian SEDEX deposits' – passed examination, subject to minor corrections.

P1A4
ORE DEPOSITS OF SE ASIA

Leaders /
Khin Zaw, Sebastien Meffre

Team Members /
Tony Crawford, Grace Cumming, Jacqueline Halpin, Ross Large, Charles Makoundi

Students /
Mohd Basril Iswadi Bin Basori, Teera Kamvong, Chun Kit Lai, You Jin Lee, Takayuki Manaka, Abhisit Salam, Quang Sang Dinh

Collaborators /
Pol Chaodumrong, Wan Fuad Wan Hassan, Azman Ghandi, Sue Golding, Teh Guan Hoe, Somboon Khositanont, Phisit Limtrakun, Mohd Rozi Umor, Sampan Singharajwarapan, Weerapan Srichan, Holly Stein, Hai Thanh Tran, Paulo Vasconcelos

The project commenced in January 2008 and was successfully completed in December 2010, building on the successful outcomes and results of the previous Loei ARC Linkage Project - 'Geochronology, metallogenesis and deposit styles of the Loei Fold Belt in Thailand and Laos'. The focus was on the mineralised fold belts and suture zones of mainland SE Asia, particularly in relation to the timing of the formation of Cu, Au, Pb and Zn deposits relative to magmatic and tectonic events, and the style, metal and hydrothermal fluid sources for the deposits in the region.

Detailed investigations were carried out in the following areas:

» Northern and southern extensions of the Loei Fold Belt in Laos and Cambodia.

» Nan Suture Zone, Thailand.

» Truong Son Fold Belt in Laos and Vietnam.

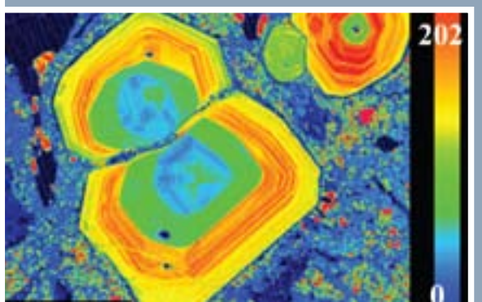
» Sukothai and Chiang Mai Fold Belts in Thailand, Yunnan and east Malaysia.

» Kontum Massif and Phuoc Son-Tam Ky Suture, and Song Ma/ Song Da Suture in Vietnam.

» Ailaoshan Fold Belt in Yunnan.

In total, the ages were determined for 292 U-Pb zircon samples using LA-ICP-MS, and all the dated rocks have been compiled into the geochronological and geochemical atlas. Approximately 50 Pb-Pb isotopic determinations have been performed on galena, and feldspar in granite, nine Re-Os dates of molybdenite, and more than fifty sulfur isotope analyses have been completed. Hundreds of fluid inclusions from several deposits were also studied, including the use of Laser Raman Spectroscopy to measure volatile species.

A number of deposits were characterised, including the shale-hosted Phuoc Son Au- and Bong Mieu orogenic Au deposits in the Phouc Son-Tam Ky Suture, Vietnam; Cu-Au skarn in the Phonsavan



District, Laos; sediment-hosted Au deposits at Selinsing, Tersang and Penjom (Malaysia); and intrusion-hosted Cu-Mo and Au-base metal deposits in eastern Cambodia. Deposit summaries highlighting mineralisation characteristics of 40 key ore deposits were produced as an atlas of ore deposits of SE Asia.

A new tectonic reconstruction model for SE Asia has been developed, based on the existing literature and a new geochemical, geochronological and ore deposits database for this project.

P1A6
TECTONIC SIGNIFICANCE AND MINERALISATION POTENTIAL OF VOLCANO-PLUTONIC BELTS AND OPHIOLITES AT THE NORTHERN END OF THE TASMAN LINE, N QUEENSLAND

Leader /
Tony Crawford

Team Member /
Mike Baker

Student /
Fiona Best

Collaborators /
Chris Fergusson, Bob Henderson, Reid Keays, Paul Polito, Ian Withnall

This project includes two overlapping strands. The first strand covers the geology, geochronology and geochemistry of diverse Early Palaeozoic units at the northern end of the Tasman Line in the area around Greenvale, N Queensland, along the eastern margin of the Palaeo- and Mesoproterozoic Georgetown Block. Key outcomes include a study covering the geochronology, geochemistry and geological mapping of volcanic units east of Greenvale.

A distinctive Late Ordovician volcano-sedimentary terrane is located within the Broken River Province of the northern Tasman Orogenic Zone. This terrane embraces Carriers Well Formation, Everetts Creek Volcanics and dismembered slivers, now structurally intercalated in the adjoining Wairuna Formation. It abuts a basement of mafic-ultramafic rocks (Gray Creek Complex) and overlying Early Ordovician deep marine sedimentary and volcanic strata (Judea Formation), which host tonalitic plutons. Based on U/Pb isotopic systematics of detrital zircon, a maximum age of Late Silurian is provided for siliciclastics of the previously undated Wairuna Formation. Geochemistry of volcanics from the Late Ordovician volcano-sedimentary terrane show them to be predominantly basaltic andesites, and andesites that show a high- K calc-alkaline to shoshonitic affinity, like broadly coeval volcanic suites represented in the intra-oceanic Macquarie Arc of the southern Tasmanides. Continent-derived arenite in the sedimentary assemblage, confirmed by the age spectrum of an arenite sample from the Carriers Well Formation, indicates that the oceanic island arc was proximal to the Late Ordovician continental margin of East Gondwana at its time of formation. A paper documenting this work has been accepted for publication in the *Australian Journal of Earth Sciences*.

The second strand is a PhD study by Fiona Best covering the petrogenesis and mineralisation potential of the Dido Batholith, which is a tonalite-dominated major crustal feature west of Greenvale that sits astride the Tasman Line, and contains unusually mafic cumulates in its core.

Mapping, and all mineral chemical and geochemical data have been collected, including Nd isotope and PGE data, indicating considerable complexity in the magmatic history of this composite intrusion. Among the mafic and ultramafic rocks occurring in the core, two distinct suites have been defined - one Fe-rich, the other relatively Fe-poor. Fiona is working to synthesize the data into a model for the petrogenesis of this important, and unusual, batholith.

P1B1
FELSIC MAGMAS IN VOLCANIC ARCS AND INTRAPLATE VOLCANIC PROVINCES – ERUPTION STYLE, DEGASSING PROCESSES, FLUID EVOLUTION AND LINKS TO MINERALISATION

Leaders /
Jocelyn McPhie, Vadim Kamenetsky

Team Members /
Sharon Allen, Isabelle Chambefort, Karsten Goemann, Emily Johnson, Maya Kamenetsky, Roland Maas, Sebastien Meffre

Students /
Andrea Agangi, Emma Brown, Glen Diemar, Pedro Fonseca, Sarah Gordee, Martin Jutzeler, Olga Vasyukova

Collaborators /
Kathy Cashman, Kathy Ehrig, Richard Fiske, Yoshi Goto, Terry Mernagh, Jorge Relvas, Carlos Rosa, Yoshihiko Tamura, Paul Wallace

This project examines volatiles and metals in felsic magmas, using a combination of melt inclusion research and physical volcanology. The mechanisms and products of degassing events that affect felsic magmas are being documented through a portfolio of projects based on modern and ancient, submarine and subaerial, mineralised and unmineralised volcanic and sub-volcanic successions.

CODES' research on young rhyolitic volcanoes in the Izu-Bonin arc focuses on the outgassing of H_2O and effects on eruption style. High hydrostatic pressure on the seafloor reduces the explosivity of eruptions, but does not prevent the formation of pumice. In fact, giant pumice is a characteristic product of eruptions in this setting. These volcanoes provide models for similar felsic volcanoes that were active during the formation of massive sulfide deposits in the Iberian Pyrite Belt and the Mount Read Volcanics. For volcanoes on land where H_2O is the dominant volatile, explosive eruptions are far more common and are crucial contributors to the global flux of H_2O from volcanic arcs. The research has also demonstrated that fluorine can be important in some rhyolitic volcanic provinces. For example, the relatively high fluorine content of the magmas which formed the Gawler Range Volcanics helps to explain the high concentrations of some trace elements (REE, Y, HFSE, Rb, in particular) and why lavas dominate over pyroclastic facies. Two PhD

theses (Andrea Agangi and Olga Vasyukova) and one Honours thesis (Emma Brown) were submitted for examination.

Based on a re-assessment of the host succession architecture, a new model has been developed for the formation of the giant Olympic Dam Cu-Au-U-REE deposit which raises the possibility that the key mineralisation event(s) may have been younger than previously thought. Although sedimentary rocks in the breccia complex have been recognised by all previous researchers, these were interpreted as maar crater-fill, and considered to be an insignificant component of the host rocks. The initial project ended in June, but has been extended for two years. Objectives are to place a more precise date on the ore formation, establish sources of the metals, and better constrain the regional context of Olympic Dam.

P1B2 (AMIRA 962)
Ni-PGE POTENTIAL OF MAFIC AND ULTRAMAFIC MAGMAS – A COMBINED MELT INCLUSIONS AND NUMERICAL MODELLING APPROACH

Leader /
Leonid Danyushevsky

Team Members /
Tony Crawford, Sandrin Feig, Andrew McNeill

Students /
Kirill Bychkov, JianXiang Guan

Collaborators /
Alexey Ariskin, Alexander Borisov, Eduard Konnikov, Allan Wilson

This project was completed successfully in 2010. The main outcomes were:

» A new model of sulfur saturation in mafic magmas, which (for the first time) takes into account the effect of melt Ni content.

» A demonstration of the role of changes in melt Ni content at the late stages of melt solidification (due to peritectic replacement of olivine by pyroxenes), was highlighted as a cause of secondary in-situ sulfide saturation.

Research focussed on understanding the interplay between magnetite and sulfide crystallisation during solidification of large gabbroid intrusions. This work is part of JianXiang Guan's PhD project, focussing on the Panzhihua Intrusion in China - one of the world's largest magmatic magnetite reserves. Major and trace element contents in magnetite, sulfide and major silicate rock-forming minerals were analysed in 40 samples collected from two vertical cross-sections through the intrusion. A major finding was that there is very little variation in mineral chemistry across the intrusion, despite very significant changes in mineral proportions — from magnetite-rich ores, through to wehrlite, gabbro, and olivine gabbro. This indicates that the intrusion was an open magma chamber, with minerals deposited from passing melts of similar compositions. Data collection will be completed in 2011.

A collaborative study with Alexander Borisov on understanding the mechanism of PGE solubility in silicate melts was completed. A paper is in press.

A project was initiated in collaboration with Allan Wilson from the University of the Witwatersrand, South Africa, on the nature of primitive melts for the Bushveld and Great Dyke intrusions in southern Africa. The project focuses on drill-core samples from the bottom sections of both intrusions that contain abundant high-Mg olivine phenocrysts, likely formed during the earliest stages of the parental melt evolution. Data collection is expected to be completed in 2011.

P1B3B
MELT-MELT IMMISCIBILITY AND THE ORIGIN OF MAGNETITE-APATITE DEPOSITS

Leader /
Paul Davidson

Team Member /
Leonid Danyushevsky

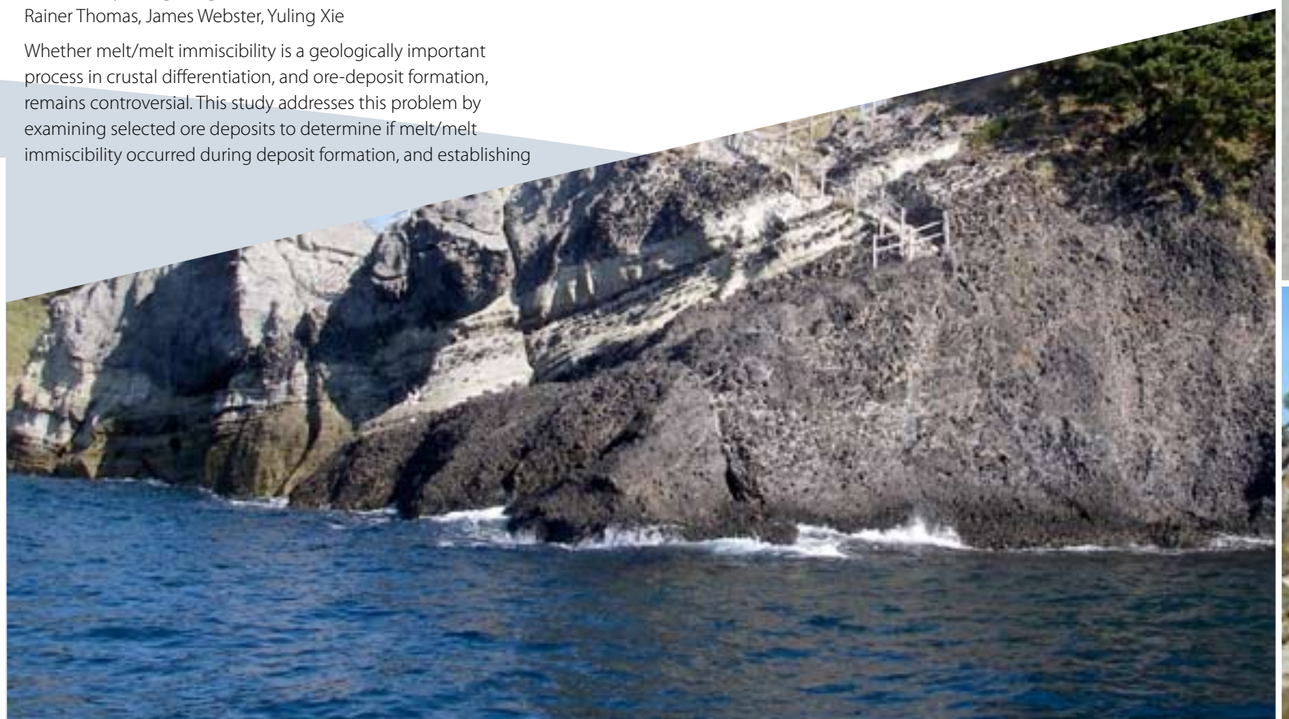
Collaborators /
Mark Dudley, Neng Jiang, Mirsaleh Mirmohammadi, John Nold, Rainer Thomas, James Webster, Yuling Xie

Whether melt/melt immiscibility is a geologically important process in crustal differentiation, and ore-deposit formation, remains controversial. This study addresses this problem by examining selected ore deposits to determine if melt/melt immiscibility occurred during deposit formation, and establishing criteria that can be used to identify its former existence. Fe-Ti oxide melt/melt immiscibility will be examined directly, and silicate-silicate melt/melt immiscibility in the origin of pegmatites will be researched via collaborative studies.

Samples from the zoned alkaline intrusion at Fanshan, China, contain abundant melt inclusions in apatite from the magnetite-apatite ore layers, but unfortunately rather less so in the mafic-ultramafic units. On the basis of microprobe analyses of crystallised inclusions, they appear to be either a peculiar mixed silicate/carbonatite melt that has unmixed during cooling, or possibly involving co-trapping of immiscible silicate and carbonatite melt fractions. The former seems more likely, but without homogenisation data this is speculative. This carbonatitic melt(s) appears to be common to all the magnetite-apatite ores at Fanshan, but is quite different to the mafic-ultramafic bulk composition of the enclosing Fanshan large layered intrusion. The carbonatite association is intriguing because the magnetite-apatite ore at Fanshan has a similar structural and stratigraphic relationship to the magnetitite and chromitite ore layers in the Bushveld intrusion. Despite the presence of abundant, apparently pristine melt inclusions, preliminary attempts at homogenisation of these inclusions have not succeeded, possibly due to the presence of abundant calcite in the crystallised inclusions. However, alternative methods are being investigated.

A paper was submitted to *Economic Geology* ('Mineralogy, Textures, Chemistry and Origin of the Pilot Knob Magnetite Deposit, St. Francois Mountains Terrane, southeast Missouri' by John L. Nold, Paul Davidson, & Mark A. Dudley), which brings the Pilot Knob study to a conclusion.

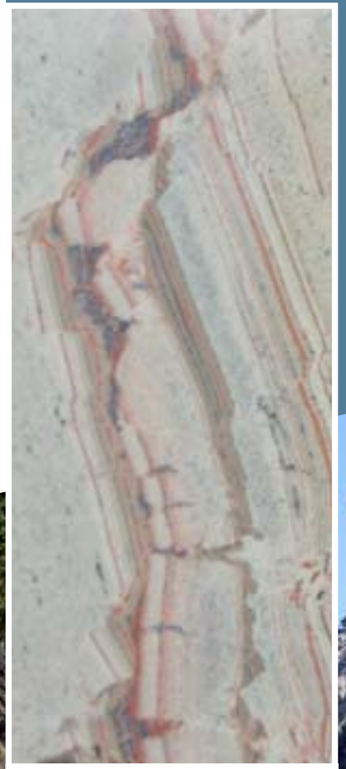
Three co-authored papers have been accepted for publication relating to melt/melt immiscibility in pegmatite areas, and one is in review. In addition, a review paper has been requested by *Mineralium Deposita*.



Outlook /

» A new SE Asia-based project to commence, which will build on the successes of the Ore Deposits of SE Asia project.

» A new extension project to continue at BHP Billiton's Olympic Dam site, researching the architecture of breccia facies at the deposit.



Program Two /

FORMATION

Objective /

To develop practical, process-based models for the formation of hydrothermal and magmatic ore deposits that will help increase discovery rates for Australia's deep earth resources.

Introduction /

Ore deposits form when chemical and physical processes cause dramatic changes in metal solubilities in hydrothermal fluids or magmas. These processes vary between deposit classes, and also between individual deposits. Evaluating the relative and absolute effectiveness of different ore-forming processes is essential for the development of new, process-based exploration models.

The Formation Program has two major research themes. Ore-Forming Processes investigates fundamental problems in ore genesis, taking advantage of CODES' unparalleled access to world-class ore deposits, well-constrained sample suites and data sets, and cutting-edge technologies. These technologies are accessed via Program 5, the nodes, and international collaborators. This theme aims to generate high profile publications, targeting high impact journals such as *Science*, *Nature*, *GCA*, *EPSL* and *Geology*.

The second research theme is Ore Deposit Characterisation. In order to understand how ore deposits form, it is essential that alteration and mineralisation features are carefully documented, both in the field and in the laboratory. This applied research activity generates essential data for understanding deposit formation and refining mineral exploration models, which makes this theme strongly linked to Program 3. Key papers and special issues describing and interpreting world-class ore deposits will be published in *Economic Geology* and *Mineralium Deposita*.

Highlights /

» P2A1A Combined PIXE and zinc isotope data suggest that source rock mineralogy controls the generation of fertile hydrothermal fluids for sediment-hosted Zn-Pb ore deposits.

» P2A2A Optical cathodoluminescence and microscopy studies, along with microanalytical studies of the stage 2 veins at Porgera, have demonstrated substantial fluctuations on Al content of quartz during vein growth.

» P2A2B High concentrations of ore metals are transported by a hydrosilicate liquid in the barren Las Pampas system, part of the Bajo de la Alumbrera complex, Argentina.

» P2A2C First regional fluid flow models incorporating interaction of variable-salinity fluids in the Irish ore field completed.

» P2B1A New postdoctoral research fellow (Dr Janina Micko) and PhD candidate (Marc Rinne) appointed. Embedded research activities have led to the utilisation of CODES' research in ongoing exploration activities.

» P2B1B Through U-Pb dating of zircons from 15 intrusive complexes, two phases of Jurassic intrusive activity related to Fe-Cu-Au mineralisation have been constrained in the Luzong volcanic basin, China.

» P2B1D All five PhD students working on the alkalic project (Adam Bath, Jacqueline Blackwell, Heidi Pass, Janina Micko (MDRU) and Wojciech Zukowski) completed their theses.

» P2B3B Susan Belford completed her PhD on the Jaguar VHMS deposit in Western Australia.

Leader /
David Cooke

Team Members /
Thomas Bissig, Stuart Bull, Zhaoshan Chang, Huayong Chen, Stephen Cox, Leonid Danyushevsky, Garry Davidson, Bruce Gemmell, Marcel Guillong, Angela Halfpenny, Anthony Harris, Julie Hunt, Vadim Kamenetsky, Lyudmyla Koziy, Jamie Laird, Ross Large, Andrew McNeill, Jocelyn McPhie, Sebastien Meffre, Janina Micko, Karin Orth, Bence Paul, Chris Ryan, Richard Tosdal, Jamie Wilkinson, Khin Zaw

PhD Students /
Mohd Basril Iswadi Bin Basori, Adam Bath, Susan Belford, Heidi Berkenbosch, Jacqueline Blackwell, Ana Liza Cuison, Nathan Fox, Sarah Gilbert, Brendan McGee, Claire McMahon, Heidi Pass, Marc Rinne, Julia Rutkowski (BGR, Germany), Francisco Jose Testa (Universidad del Sur), Selina Wu, Lejun Zhang (Hefei University), Wojciech Zukowski

Masters Students /
Jo Condon, Paul Ferguson, Margy Hawke, Md. Sakawat Hossain (RSES, ANU), Liang Ma (Hefei University), Neil Macalalad, Bin Qian (Hefei University), Nathan Steeves (University of Ottawa), Leo Subang

Honours Students /
Hamish Johns, Ting Kor, Alex Lukomskyj (RSES, ANU), Katherine Webb

Collaborators /
AAAS GSA/USGS CONGRESSIONAL FELLOW, USA – Larry Meinert
ANGLO AMERICAN – David Braxton
ANU – Charlotte Allen, Ian Campbell
BARRICK GOLD – Paul McInnes
COLORADO SCHOOL OF MINES, USA – Thomas Monecke
CONSULTANT, PHILIPPINES – Joey Garcia
CSIRO – John Walshe
EMMERSON RESOURCES – Grant Osborne
GEOLOGICAL SURVEY OF CANADA – Wayne Goodfellow, Jan Peter
GEOLOGICAL SURVEY OF NEW SOUTH WALES – Ian Percival
GEOSCIENCE AUSTRALIA – Geoff Fraser, Roger Skirrow
HANOI UNIVERSITY OF GEOLOGY AND MINING, VIETNAM – Hai Thanh Tran
HEFEI UNIVERSITY OF TECHNOLOGY, CHINA – Yu Fan, Feng Yuan, Taofa Zhou
IMPERIAL COLLEGE LONDON, UK – Dominik Weiss
IMPERIAL METALS, CANADA – Patrick McAndless, Chris Rees
INSTITUTE OF GEOLOGICAL AND NUCLEAR SCIENCES, NEW ZEALAND – Cornel de Ronde, Kevin Faure
INSTITUTE OF GEOLOGY, CHINESE ACADEMY OF GEOLOGICAL SCIENCES, CHINA – Zhiming Yang
IVANHOE AUSTRALIA – Florinio Lazo, Rohan Wolfe
LAURENTIAN UNIVERSITY, CANADA – Steve Piercey
MCGILL UNIVERSITY, CANADA – Jeanne Paquette
MOROBE MINING JOINT VENTURE, PNG – Dave Finn, Chris Muller, Simon Shakesby, Betty Tekeve
NEWCREST MINING – Dean Collett, John Holliday
NEWCREST MINING, PNG – Jon Rutter
NORTHERN TERRITORY GEOLOGICAL SURVEY – Masood Ahmad
OZ MINERALS – Hamish Freeman
QUEEN'S UNIVERSITY, CANADA – Dan Layton-Matthews
SIMON FRASER UNIVERSITY, CANADA – Derek Thorkelson
TABIAT MOALLEM UNIVERSITY, IRAN – Zahra Bonyadi, Behzad Mehrabi
UNIVERSITY KEBANGSAAN, MALAYSIA – Wan Fuad Wan Hassan
UNIVERSITY OF ALBERTA, CANADA – Robert Creaser
UNIVERSITY OF BRITISH COLUMBIA, CANADA – Greg Dipple, Jim Mortensen
UNIVERSITY OF LISBON, PORTUGAL – Miguel Gaspar
UNIVERSITY OF MALAYA – Azman Ghandi, Teh Guan Hoe
UNIVERSITY OF OTTAWA, CANADA – Mark Hannington
UNIVERSITY OF WESTERN AUSTRALIA – Marco Fiorentini

Core Projects /

Theme 2A – Ore-forming Processes

P2A1A Transition metal speciation and isotope systematics of source rocks for sediment- and volcanic-hosted ores

P2A2A Fracture arrays in intrusion-related ore systems – controls on the dynamics of fluid flow, vein formation and the generation of giant deposits

P2A2B Determination of gold and other metals in fluid inclusions

P2A2C Modelling fluid flow in the Irish Zn-Pb ore field

P2A3 Efficiency of ore-forming processes

Theme 2B – Ore Deposit Characterisation

P2B1A Exploring the porphyry environment

P2B1B Polymetallic mineralisation and associated magmatic and volcanic activity in Cretaceous volcano-sedimentary basins of eastern China

P2B1D Shallow and deep-level alkalic mineral deposits

P2B3A Fluids that form high-salinity, volcanic-hosted massive sulfide deposits

P2B3B Genesis of volcanic-hosted Cu-Pb-Zn-Ag-Au massive sulfide deposits

P2B3C Hydrothermal event recognition and target vectoring in sedimentary strata

P2B3D Active base- and precious-metal-rich massive sulfide depositions

P2B4 Iron oxide copper-gold and related deposit types

THE ABOVE LIST REPRESENTS ACTIVE PROJECTS IN 2010

Project Summaries /

P2A1A
TRANSITION METAL SPECIATION AND ISOTOPE SYSTEMATICS OF SOURCE ROCKS FOR SEDIMENT – AND VOLCANIC-HOSTED ORES

Leader /
Jamie Wilkinson

Team Members /
David Cooke, Bruce Gemmell, Jamie Laird, Ross Large, Chris Ryan

Collaborator /
Dominik Weiss

PIXE analyses have shown that the principal mineral hosts for zinc in the basement source rocks that provided metals for hydrothermal fluids in the Irish ore field are chlorite and a fine-grained greywacke matrix component, composed largely of illite. Thermodynamic modelling predicts chlorite breaking down to liberate metals at T = 250-300 °C. High precision double-spike zinc isotope analyses of basement whole-rock samples and cold acid leachates show a correlation between the proportion of leachable zinc in the samples and the isotopic composition of the leachates. Fertile ore fluids may be only produced where the source rocks contain zinc in labile sites. The zinc isotope compositions observed are interpreted to reflect a combination of a fertile/infertile hydrothermal fluid signature derived from the source rocks, during the metal extraction and fractionation processes, which may occur during sphalerite precipitation. Sulfur isotope compositions reflect the presence or absence of a bacteriogenic sulfide trap.

P2A2A
FRACTURE ARRAYS IN INTRUSION-RELATED ORE SYSTEMS - CONTROLS ON THE DYNAMICS OF FLUID FLOW, VEIN FORMATION AND THE GENERATION OF GIANT DEPOSITS

Leader /
Stephen Cox

Team Members /
David Cooke, Angela Halfpenny

Students /
Md. Sakawat Hossain, Alex Lukomskyj

This project explored stress field evolution during gold mineralisation at Porgera, PNG, and examined the influence that changes in stress field orientations and failure modes had on mineralisation styles. The transition from low grade, distributed mineralisation (stage 1) to localised high grade mineralisation (stage 2) was associated with the growth of the Romane Fault

network. Textural and compositional banding in stage 2 veins indicates multiple episodes of vein growth and sealing. Each cycle of vein growth is marked by deposition of an initial zone rich in roscoelite and pyrite, together with Al-rich quartz. The early Au-rich phase of each cycle is overgrown by a quartz-rich zone with low Au grades and marked oscillatory zoning in quartz's Al contents. Individual veins may contain several of these gold-rich to gold-poor cycles of vein growth. Each cycle of vein growth is interpreted to be triggered by breaching of the magmatic-hydrothermal fluid reservoir.

P2A2B
DETERMINATION OF GOLD AND OTHER METALS IN FLUID INCLUSIONS

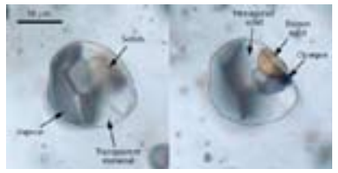
Leader /
Jamie Wilkinson

Team Members /
David Cooke, Leonid Danyushevsky, Marcel Guillong, Vadim Kamenetsky

Student /
Sarah Gilbert

Collaborator /
David Braxton

Two Cu-Au porphyry systems were studied: the Boyongan deposit in the Philippines, and Las Pampas in Argentina - a barren satellite of the Bajo de la Alumbrera deposit. Brine inclusions are abundant in a quartz stockwork vein sample hosted by the inter-mineral diorite porphyry at Boyongan. LA-ICP-MS analyses confirmed the cation predominance Na>K>Fe, with an average ratio of 57:27:16. Gold was not detected, despite detection limits down to 0.11 ppm, but silver was determined at 5-20 ppm. In Las Pampas quartz-magnetite veins, the most common inclusion type are unusual vapour-solid inclusions in which the vapour typically fills ~50% of the inclusion volume and forms a planar or irregular contact with the principal transparent phase. Gold was only detected in one inclusion at the ppm level. Overall, the inclusions have bulk compositions similar to aqueous brines from Bajo de la Alumbrera, but differ in the concentrations of salt and (probably) silicate components.



SOLID-VAPOUR INCLUSION FROM LAS PAMPAS QUARTZ-MAGNETITE VEINS, BAJO DE LA ALUMBRERA (SAME INCLUSION AT DIFFERENT DEPTHS OF FOCUS).

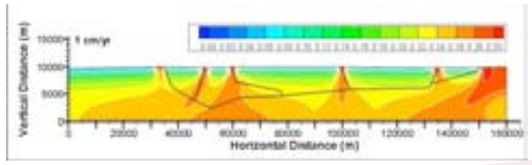
P2A2C
MODELLING FLUID FLOW IN THE IRISH Zn-Pb ORE FIELD

Leaders /
Jamie Wilkinson, Stuart Bull

Team Member /
Lyudmyla Koziy

This project aims to produce the first model for fluid flow in the Irish Midlands Basin that incorporates interaction of variable salinity fluids. Objectives are to assess the variables that allow extensive basement flow; evaluate the competition between halite-saturated and gypsum-saturated brines; and understand the controls of the flow patterns, in particular the depth of fluid penetration.

During the year, a finite element mesh has been constructed of a schematic cross section of the basin, and modelling of various scenarios commenced. Initial results suggest an important role for an upper crustal detachment for focusing lateral flow of brines (particularly southward-directed) and the significance of this mechanism for controlling discharge from faults. Although flow patterns and pathways indicated by the initial model scenarios are appropriate for ore formation, fluid velocity and temperature are both lower than expected. Model parameters are currently being adjusted to address this issue.



FLOW MODEL FOR THE IRISH MIDLANDS BASIN SHOWING SALINITY DISTRIBUTION AFTER 15 MY, ILLUSTRATING DOWNWARD MOVING PLUMES OF BRINES SOURCED FROM SUBAERIAL OR SHALLOW WATER EVAPORITIC ENVIRONMENTS, NOTABLY THE LONGFORD DOWN MASSIF AT THE RIGHT HAND SIDE OF THE MODEL. DARK LINES REPRESENT FAULTS.

P2A3
EFFICIENCY OF ORE-FORMING PROCESSES

Leaders /
Zhaoshan Chang, David Cooke, Jamie Wilkinson

Team Member /
Chris Ryan

Collaborators /
Joey Garcia, Miguel Gaspar, Larry Meinert, Jeanne Paquette, Zhiming Yang

The following topics are currently being investigated:

» High-sulfidation epithermal deposits generally form in two stages. While the genesis of early stage silicic and advanced argillic alteration is well understood, late stage mineralisation processes are still debated. Many models have been proposed, including the recent vapour contraction model. This project is developing a new model to explain the mineralisation process, based on research into the Lepanto deposit, Philippines.

» Trails of regularly spaced Au grains with 8 or 6-sided shapes occur in dendritic quartz, UST quartz, and vein dykes in intrusive rocks at the Bilihe Au deposit, China. Geochemical analyses and crystallographical modelling are ongoing, but it is tentatively proposed that the Au grains were deposited from an Au-dominant melt.

» Garnet colours change systematically with distance from the causative intrusion in skarn deposits – a powerful tool in exploration. The relationship between garnet colours and chemical compositions is being investigated, using microprobe and LA-ICP-MS analyses.

P2B1A
EXPLORING THE PORPHYRY ENVIRONMENT

Leaders /
Anthony Harris, David Cooke

Team Member /
Janina Micko

Students /
Ana Liza Cuison, Nathan Fox, Ting Kor, Marc Rinne

Collaborators /
Charlotte Allen, Ian Campbell, Dean Collett, Robert Creaser, Kevin Faure, Dave Finn, John Holliday, Chris Muller, Ian Percival, Simon Shakesby, Betty Tekeve

CODES and Newcrest are working together to maximise opportunities for the discovery of new porphyry-related gold resources. This is being achieved through ongoing training, which is underpinned by targeted research activities designed to advance conceptual models and exploration techniques. This approach has led to improved understanding of Newcrest's porphyry and epithermal deposits in Australia (Cadia), PNG (Golpu-Wafi), and Fiji (Wasoi-Waivaka). Ongoing field-based research has led to the revision of logging procedures and revised methods of describing hydrothermal alteration - so critical in the exploration of large porphyry systems in the southwest Pacific. Exploration field programs apply a multipronged approach that considers the application of conventional and advanced geochemical techniques, including mineral chemistry determined by SWIR and LA-ICP-MS. The research team has grown to include Janina Micko, who joined CODES from MDRU after completion of her PhD on the Galore porphyry Au deposit. Marc Rinne commenced his PhD on the Golpu porphyry during the year.

P2B1B
POLYMETALLIC MINERALISATION AND ASSOCIATED MAGMATIC AND VOLCANIC ACTIVITY IN CRETACEOUS VOLCANO-SEDIMENTARY BASINS OF EASTERN CHINA

Leaders /
Taofa Zhou, David Cooke

Team Members /
Zhaoshan Chang, Sebastien Meffre

Students /
Liang Ma, Bin Qian, Lejun Zhang

Collaborators /
Yu Fan, Feng Yuan

Significant progress has been made in attaining a better understanding of the polymetallic mineralisation and associated magmatic and volcanic activity in the Luzong basin, middle and lower Yangtze River, eastern China. There are at least 34 plutons in the basin. LA-ICP-MS zircon U-Pb dating of 15 of the plutons has shown that intrusive activity occurred between 134 and 123 Ma. The intrusive rocks can be divided into two stages. Early stage (134~130 Ma) monzonite-diorite plutons crop out in the northern part of the basin – their emplacement was controlled by NNE-trending structures. Late stage plutons (129~123 Ma) include several syenites that crop out in the southern part of the basin, and A-type granites (126~123 Ma) that crop out on its southeast margin.

P2B1D
SHALLOW AND DEEP-LEVEL ALKALIC MINERAL DEPOSITS

Leaders /
David Cooke, Richard Tosdal

Team Members /
Thomas Bissig, Jocelyn McPhie

Students /
Adam Bath, Jacqueline Blackwell, Heidi Pass, Janina Micko, Wojciech Zukowski

Collaborators /
Greg Dipple, Patrick McAndless, Paul McInnes, Chris Rees, Jon Rutter

The aims are to document the characteristics and determine the genesis of alkalic porphyry deposits of British Columbia, and alkalic epithermal deposits of PNG and Australia. The project involves collaboration with UBC and is supported by nine industry sponsors. Additional financial support derives from grants from the Natural Sciences and Engineering Research Council of Canada (NSERC) and Geoscience BC. All five PhD students working on the alkalic project successfully completed their theses and were awarded their degrees during the year. All team members made significant progress towards finalising their manuscripts for a special issue of *Economic Geology* summarising project results.

P2B3A
FLUIDS THAT FORM HIGH-SALINITY, VOLCANIC-HOSTED MASSIVE SULFIDE DEPOSITS

Leader /
See below

Investigations begun by the late Mike Solomon into the deposition mode and origin of the Lombador ore body, Neves Corvo, are being completed by John Walshe (CSIRO) using sulfur isotopic data from the Lombador ore and stockwork veins.

P2B3B
GENESIS OF VOLCANIC-HOSTED Cu-Pb-Zn-Ag-Au MASSIVE SULFIDE DEPOSITS

Leader /
Bruce Gemmell

Team Members /
Garry Davidson, Ross Large, Andrew McNeill, Khin Zaw

Students /
Mohd Basril Iswadi Bin Basori, Susan Belford, Jo Condon, Paul Ferguson, Margy Hawke, Brendan McGee, Nathan Steeves, Selina Wu

Collaborators /
Azman Ghandi, Teh Guan Hoe, Mark Hannington, Jim Mortensen, Wan Fuad Wan Hassan, Hai Thanh Tran

This project is investigating the spectrum of massive sulfide deposit types. Research was undertaken in the past year on deposits at Fossey-Hellyer-Que River-Mt Charter (Tasmania), Jaguar (Western Australia), DeGrussa (Western Australia), Palmer (Alaska), Baiyinchang (China), Duc Bo (Vietnam), Tasik Chini (Malaysia) and Tala Hamza (Algeria). In addition, a detailed geochronological study of the host successions in the Mount Read Volcanic Belt continued.

P2B3C
HYDROTHERMAL EVENT RECOGNITION AND TARGET VECTORING IN SEDIMENTARY STRATA

Leader /
Bruce Gemmell

Collaborators /
Wayne Goodfellow, Mark Hannington, Dan Layton-Matthews, Thomas Monecke, Jan Peter, Steve Piercey

This CAMIRO (Canadian Mining Industry Research Organization - Exploration Division)-funded project is developing an improved understanding of the concentrations and behaviour of trace metals associated with volcanic-hydrothermal processes in marine sedimentary and volcano-sedimentary successions.

Research is progressing, which includes the development of new mineralogical, geochemical, and isotopic tools to discriminate potentially mineralised versus unmineralised horizons in many mineralised districts. A successful sponsors meeting was held in Keystone, Colorado, in October.

P2B3D
ACTIVE BASE- AND PRECIOUS-METAL-RICH MASSIVE SULFIDE DEPOSITIONS

Leader /
Bruce Gemmell

Students /
Heidi Berkenbosch, Julia Rutkowski

Collaborator /
Cornel de Ronde

This project is investigating the ore and gangue mineralogy, textures, paragenesis, mineral chemistry and sulfur isotopes of the sulfide-sulfate chimneys on the modern seafloor.

Activities included Heidi Berkenbosch's PhD project at Brothers volcano in the Tonga-Kermadec arc, which is being conducted in collaboration with GNS Science, New Zealand. In addition, Julia Rutkowski, a PhD student with the BGR in Germany, spent two weeks at CODES undertaking trace element analyses of fluid inclusions and sulfur isotope analyses on samples from black smoker chimneys from the Tonga Arc.

P2B4
IRON OXIDE COPPER-GOLD AND RELATED DEPOSIT TYPES

Leader /
Garry Davidson

Team Members /
Huayong Chen, Julie Hunt, Ross Large, Sebastien Meffre, Karin Orth, Bence Paul, Khin Zaw

Students /
Hamish Johns, Claire McMahon

Collaborators /
Masood Ahmad, Zahra Bonyadi, Marco Fiorentini, Geoff Fraser, Hamish Freeman, Florinio Lazo, Behzad Mehrabi, Grant Osborne, Roger Skirrow, Derek Thorkelson, Rohan Wolfe

This project aims to improve the understanding of IOCGs and related systems. Achievements in 2010 included:

» Molybdenum isotope study of the Merlin deposit.

» Imaging of Ar-Ar samples and preparation of a geochronological manuscript on Prominent Hill.

» Revision of stable isotope and fluid inclusion work, and resubmission of a manuscript on the Wernecke breccias.

» Honours study of the Northern Star mineralisation at Tennant Creek, focussing on aspects of the geochronology that require modification of genetic models.

» A collaboration between CODES and Tabiat Moallem University resulted in acceptance of a paper in *Chemical Geology* on Se-Chahun, Iran, dealing with aspects of element mobility in this iron oxide-apatite deposit.

» The final report for the Coronation Hill U-PGE-Au system is nearly complete, with the geochronology, geochemistry and paragenesis of the ores well-progressed. A small collaboration on PGE genesis at Coronation Hill was undertaken with Marco Fiorentini from UWA.

Outlook /

» P2A1A Submission of paper to *Nature Geoscience*.

» P2A2A Submission of two papers dealing with the Porgera gold deposit.

» P2A2B Submission of paper to *Nature Geoscience*.

» P2A2C Submission of paper to *Geology*.

» P2B1A Publication of research results from CODES-Newcrest collaborative research. Initiation of PhD study of Namosi, Fiji.

» P2B1B A short course to be held at Hefei University. SEG Student Chapter field trip to Luzong, and other areas in the middle and lower reaches of the Yangtze metallogenic province, China, is planned for May 2011.

» P2B1D Publication of the Alkalic project special issue in *Economic Geology*.

Program Three /

DISCOVERY

Objective /

To develop techniques for the acquisition and interpretation of ore deposit geophysical and geochemical data that will assist in the discovery of Australia's deep earth resources.

Introduction /

The Discovery Program leverages off CODES' extensive, broad-based research expertise to enhance the development of geophysical, geochemical and geological models for specific world-class ore deposits. The program is now structured around two key themes: innovative techniques for discovery, and integrated exploration models for discovery.

CODES has built on its traditional strengths in ore deposit geology and geochemistry by expanding its geophysics capability, which now employs a comprehensive suite of geophysical and mathematical techniques in a diverse mix of projects around the world.

Highlights /

» AMIRA Project P1022, the rapid approximate inversion of TEM data, commenced and the method has been implemented for airborne TEM (moving loop) data.

» Seismic wave speed structure tomographic sections were determined along a pilot transect of the upper crust using ambient seismic energy.

» Session entitled 'Innovations in Geophysical Inversion' led by Anya Reading and Malcolm Sambridge at the Australian Society for Exploration Geophysics meeting in Sydney, August 2010.

» Successful completion of Geochemical and Geological Halos in Green Rocks and Lithocaps (AMIRA project P765A).

» Development and publication of a new genetic model for sediment-hosted gold deposits.

» The development of new models for Ni-Cu-PGE mineralisation, involving multi-stage processes leading to 'sedimentary-style' deposition of pre-formed chromite, sulfide and platinum group metals (PGM) grains under magmatic conditions.

» Design, development and initiation of new post-doctoral study by Steve Micklethwaite entitled 'Enabling Blind Exploration - Identifying Hidden Structure with Faults, Fractals and Geomorphology'.

Leader /
Andrew McNeill

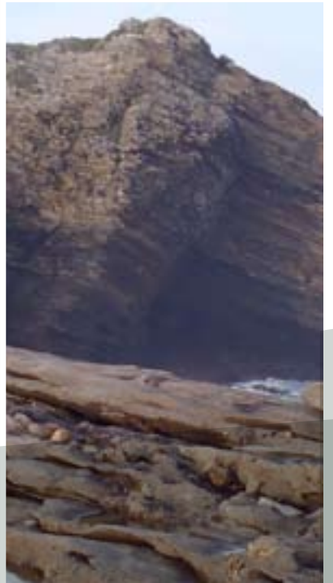
Team Members /
Mike Baker, Ron Berry, Stuart Bull, Zhaoshan Chang, Huayong Chen, David Cooke, Tony Crawford, Leonid Danyushevsky, Garry Davidson, Jeff Foster, Bruce Gemmell, Leon Graham, Norman Heckscher, Dave Hutchinson, Shaun Inglis, Vadim Kamenetsky, Ross Large, Sebastien Meffre, Steve Micklethwaite, Ross Olsen, Anya Reading, Michael Roach, Ralf Schaa, Rob Scott, David Selley, Helen Thomas, Tony Webster, Wojciech Zukowski

PhD Students /
Mathieu Ageneau, Victoria Braniff, Lindsey Clark, Matt Cracknell, Sarah Gilbert, Roisin Kyne, Hugo Galvan, Dan Gregory, Nic Jansen, Alexey Lygin, Jeff Steadman, Bronto Sutopo

Masters Students /
Gabe Sweet (Lakehead University, Canada), Daud Silitonga

Honours Student /
Kyen Knight

Collaborators /
ANU – Nicholas Rawlinson, Malcolm Sambridge
CONSULTANT – Noel White
CSIRO – Rob Hough, John Walshe
FULLAGAR GEOPHYSICS – Peter Fullagar
IMPERIAL COLLEGE LONDON – Clara Wilkinson, Jamie Wilkinson
JAMES COOK UNIVERSITY – Tom Blenkinsop
LAKEHEAD UNIVERSITY, CANADA – Peter Hollings
MINERAL RESOURCES TASMANIA – Ralph Bottrill, Jafar Taheri
OTAGO UNIVERSITY, NEW ZEALAND – Dave Craw
OZ MINERALS – Mark Allen, Jorge Benavides, Hamish Freeman
RUSSIAN ACADEMY OF SCIENCE, URALS BRANCH – Valery Maslennikov
SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY, USA – Colin Paterson
UNIVERSITY OF OTTAWA – Jeff Hedenquist
UNIVERSITY OF SYDNEY – Patrice Rey



Core Projects /

Theme 3A – Innovative Techniques for Discovery

P3A1C The rapid approximate inversion of TEM data (AMIRA P1022)

P3A2A Ambient seismic energy techniques

P3A3A Data inference techniques applied to diverse geoscientific datasets

Theme 3B – Integrated Exploration Models for Discovery

P3B1A Geochemical and geological halos in green rocks and lithocaps - The explorer's toolbox for porphyry and epithermal districts (AMIRA P765A)

P3B1C Low- and high- sulfidation epithermal mineral deposits

P3B2A Sediment- and volcanic-hosted gold-arsenic deposits: genesis & exploration models

P3B3A Shales and carbonates - improved vectors for Rosebery and Hercules style VHMS

P3B5A The Tweefontein Sector of the Platreef, South Africa

P3B5B The characterisation of magmatic sulfide systems

P3B5C The geology, geochemistry and genesis of the Avebury Ni deposit - implications for exploration

P3B6A Structure and formation of the Savage River magnetite deposit

P3B7A Iron oxide copper-gold and related deposit types

THE ABOVE LIST REPRESENTS ACTIVE PROJECTS IN 2010

Project Summaries /

P3A1C (AMIRA P1022)
THE RAPID APPROXIMATE INVERSION OF TEM DATA

Leaders /
Jeff Foster, Peter Fullagar

Team Member /
Ralf Schaa

The project commenced during the year with AngloGold Ashanti, Gold Fields, Rio Tinto and Mira Geoscience as sponsors. This initiative is designed to build on the fast, approximate 3D TEM inversion scheme developed in Ralf Schaa's PhD thesis, which is based on EM modelling at the resistive limit. In this method, the TEM data are converted to magnetic moments via time integration. In effect, the moment transformation converts the problem from one associated with nonlinear 3D TEM inversion into one involving a linear 3D magnetic inversion. The resistive limit response is realised as a linear combination of a discretized 3D target response and a continuous host response. A starting model is constructed from conductivity depth images of the TEM profiles. In addition, the inversion is constrained by geological information and by standard potential field inversion devices, such as depth weights. The underlying model is both geological and petrophysical. The inverse problem is solved using a fast steepest-descent algorithm. This methodology, which enables approximate 3D inversion in minutes, rather than hours, has been successfully tested using synthetic fixed-loop TEM examples, and on real fixed-loop TEM field data.

The Vpem3D algorithm has been modified with the implementation of total field inversion and adapted to allow for airborne TEM (moving loop).

P3A2A
AMBIENT SEISMIC ENERGY TECHNIQUES

Leader /
Anya Reading

Team Members /
Leon Graham, Norman Heckscher

Collaborator /
Nicholas Rawlinson

Ambient seismic energy techniques are new methods that use natural and man-made background or ambient energy to provide images of buried structure. During 2010, ambient seismic data acquired previously along a pilot line (ASET1), with 10 variably spaced stations, was processed and seismic wave speed cross sections determined. This effectively proved the ambient seismic data method concept for upper crustal scale studies.

A significant new 3D ambient seismic dataset (ASET2) was also obtained in collaboration with a geothermal exploration company. The deployment had a core of 16 stations in an irregular diamond pattern. A further six stations deployed in the latter part of the experiment were at wider station spacings to resolve deeper parts of the exploration prospect. Processing for 3D seismic wave speed structure is underway.

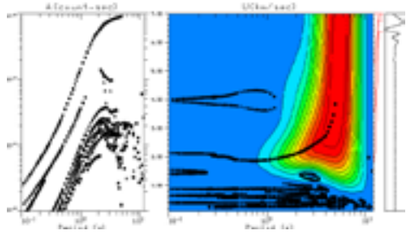


DIAGRAM SHOWS AN INTERMEDIATE STAGE IN PROCESSING THE SEISMIC WAVEFORM (SHOWN TO THE RIGHT OF THE IMAGE) TO PRODUCE A DISPERSION CURVE.

P3A3A
DATA INFERENCE TECHNIQUES APPLIED TO DIVERSE GEOSCIENTIFIC DATASETS

Leader /
Anya Reading

Team Members /
Jeff Foster, Michael Roach

Student /
Matt Cracknell

Collaborator /
Malcolm Sambridge

Inference refers to the process of extracting robust results, or gaining knowledge from a dataset or observed information. This process is implicit in most scientific endeavours, but this project aims to explicitly investigate the application of innovative mathematical, geophysical and statistical approaches to diverse geoscience datasets. In addition to necessary background work, two major activities occurred during the year:

» A major conference session - Innovations in Geophysical Inversion – was convened by Reading and Sambridge at the ASEG meeting in Sydney during August. The presentations generated heated discussion and resulted in an invitation to write a feature article on the new approaches.

» Machine learning style computational approaches to data inference were investigated, based on the PhD research of Matt Cracknell. This project began in July.

P3B1A (AMIRA P765A)
GEOCHEMICAL AND GEOLOGICAL HALOS IN GREEN ROCKS AND LITHOCAPS - THE EXPLORER'S TOOLBOX FOR PORPHYRY AND EPITHERMAL DISTRICTS

Leaders /
David Cooke, Bruce Gemmell, Zhaoshan Chang

Team Members /
Mike Baker, Huayong Chen, Jeff Hedenquist, Peter Hollings, Shaun Inglis, Noel White, Clara Wilkinson, Jamie Wilkinson

Students /
Nic Jansen, Roisin Kyne, Gabe Sweet

This project was completed on time and within budget in December. The research team developed and validated new geochemical techniques that help predict the likely direction and distance to porphyry-style mineralised centres, either in the deeply eroded 'green rock' environment, where propylitic alteration predominates, or in the intensely clay-altered 'lithocap' environment, where porphyry or high sulfidation-style epithermal mineralisation may be hidden in intense clay and silicic alteration. Using advances in LA-ICP-MS, the team established that subtle hypogene geochemical dispersion halos can be detected several kilometres beyond the limits of geochemical anomalies that are detected by conventional rock-chip sampling techniques; thereby extending the detectable geochemical footprint of porphyry mineralised centres. The team also developed geochemical tools that discriminate between environments (porphyry, epithermal, metamorphic), and made significant progress towards developing and testing fertility indicators (i.e., discriminating large, small and barren systems).

P3B1C
LOW- AND HIGH- SULFIDATION EPITHERMAL MINERAL DEPOSITS

Leaders /
Bruce Gemmell, David Cooke

Team Members /
Steve Micklethwaite, Wojciech Zukowski

Students /
Mathieu Ageneau, Lindsey Clark, Hugo Galvan, Daud Silitonga, Bronto Sutopo

Collaborators /
Tom Blenkinsop, Patrice Rey

The geology and genesis of low- and high-sulfidation epithermal deposits are being investigated in Australia and in the southwest Pacific region. Research has concentrated on determining the geological and geochemical constraints on the formation of these deposits, which will lead to improved genetic and exploration models.

Low sulfidation deposits

» Research continued on the Newcrest-funded deposit to district-scale study of the Gosowong goldfield, Halmahera Island, Indonesia. Steve Micklethwaite finished his investigation of the structural characteristics of Gosowong, which led to the initiation of a new post-doctoral study entitled 'Enabling Blind Exploration - Identifying Hidden Structure with Faults, Fractals and Geomorphology'. This project utilises quantitative geomorphological technology to identify the location of mineralised faults and veins from subtle landscape signatures. The research combines these methods with analyses of the fractal behaviour of fault-vein networks to provide geometric vectors to potentially mineralised structures.

» Lindsey Clark's PhD project, investigating the geology and genesis of the Kencana epithermal Au-Ag deposit at Gosowong, is providing the first detailed study of the deposit via geological, structural, mineralogical and geochemical investigations. Masters of Economic Geology student, Daud Silitonga, is investigating the Toguraci epithermal veins that crosscut the low grade Bora porphyry Cu-Au prospect in the Gosowong district.

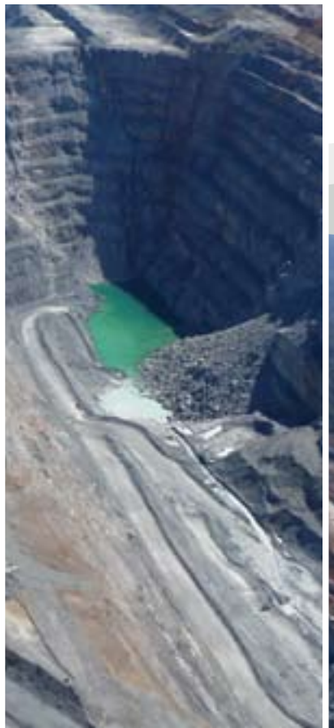
» Hugo Galvan's PhD project is investigating the geological and geochemical evolution of carbonate-base-metal Ag-Au epithermal veins in the Palmarejo District, Chihuahua, Mexico. The study is being funded by Coeur d'Alene and aims to develop a more detailed understanding of the geological evolution of the district. This will be achieved by investigating the mineralisation history, geochemistry and relationships to grade distribution, plus documenting the vein stratigraphy, paragenesis, spatial and temporal distribution of the alteration assemblages and geochemistry of the mineralising fluids.

» PhD student, Mathieu Ageneau, continues to study the low-sulfidation Ladolam Au deposit in Papua New Guinea, supported by Newcrest. During 2010, the research focused on the mineralogy of the Lienetz and Minifie ore bodies and, more specifically, the geochemistry of the main ore mineral - refractory pyrite. The study is also investigating the geology, alteration, and metal zoning of the Kapit ore body.

» Following a short-term postdoctoral study in 2009, Wojciech Zukowski completed a six-month study of the Ares intermediate and low sulfidation epithermal silver-gold deposit in southern Peru. The project, funded by Hochschild Mining, focused on developing geological, mineralogical and lithogeochemical indicators to epithermal veins that will help exploration activities in the Ares district. The study was completed mid-year, and comprised four months field work at the site, followed by laboratory analyses and report writing at CODES.

High sulfidation deposits

Bronto Sutopo is close to completing his PhD research on the high- and low-sulfidation mineralisation in the Martabe district, Indonesia. His thesis will significantly improve the understanding of the geologic setting and ore genesis, as well as developing criteria for enhanced exploration in the district. His thesis is expected to be submitted early in 2011.



P3B2A
SEDIMENT- AND VOLCANIC-HOSTED GOLD-ARSENIC DEPOSITS: GENESIS & EXPLORATION MODELS

Leaders /
Ross Large, Stuart Bull

Team Members /
Leonid Danyushevsky, Garry Davidson, Shaun Inglis, Sebastien Meffre, Rob Scott, Helen Thomas.

Students /
Sarah Gilbert, Dan Gregory, Jeff Steadman

Collaborators /
Dave Craw, Peter Hollings, Rob Hough, Valery Maslennikov, Colin Paterson, John Walshe

This project focuses on pyrite textures, geochemistry and isotopes in a wide range of gold deposits to elucidate the origin, sources and timing of pyrite and gold. The new LA-ICP-MS pyrite mapping technology developed at CODES is a key tool in this study, which enables the trace element and gold hydrothermal history of deposits to be determined. A portion of this work forms part of AMIRA project P1041: 'The application of new technologies to gold deposits', sponsored by AngloGold Ashanti, Newcrest, Newmont, G-Resources, Sipa and Issara.

The following deposits were studied in 2010:

» Wafi high sulfidation epithermal gold deposit, PNG - Focusing on the pyrite textures, mineralogy and timing of gold, and the geochemical fingerprint of the gold event.

» Mt Olympus sediment-hosted gold deposit in Western Australia - This study involves a comparison of textures and gold mineral associations with the Carlin system in Nevada.

» McPhillamys volcanic/sediment-hosted disseminated gold deposit in NSW - The aims are to determine the pyrite-gold mineralogy, timing of gold, S & Pb isotope characteristics of pyrite, and the alteration mineralogy/geochemistry.

» Witwatersrand Carbon Leader Reef at West Wits, South Africa – The focus is on the textures and chemistry of pyrite and relationships to gold and uranium mineralogy. The research addresses the question: "What are the potential sources of the various pyrite types and related gold?"

» Kumtor gold deposit in the Tian Shan Belt, Central Asia - In this collaboration with Valery Maslennikov, RAS, the pyrite in black shale wall rocks and the ore zones have been studied. Nodular diagenetic pyrite in the carbonaceous shale host sequence are enriched in gold and tellurium, which may be the original source of these elements in the ores. S and Pb isotopes are being used to constrain sources and timing.

» Otago Gold Province, New Zealand - Pyrite from the Macraes deposit, and from schists throughout the province, has been studied to shed light on the hydrothermal history and relative timing of gold input. A geochemical fingerprint of ore-related pyrite has been established and can be used in exploration.

» St Ives gold camp, Yilgarn, WA – Research is focused on the Kapai Slate to determine if there is evidence of early concentration of gold in organic-rich, sedimentary facies of the greenstone belt. This is part of a PhD study by Dan Gregory, conducted in collaboration with the CSIRO MDU Flagship and Gold Fields.

» Homestake Gold Mine, USA - PhD student, Jeff Steadman, is studying the footwall lithologies (Poorman Formation) to the Homestake BIF, in collaboration with South Dakota School of Mines & Technology. Research is focused on understanding the metamorphic transition from pyrite to pyrrhotite in the footwall shales, and how this may relate to the concentration of gold in the overlying carbonate facies BIF.

» Geraldton BIF-gold camp, Ontario - A second aspect of Jeff Steadman's PhD research is to investigate the source and mechanisms of gold concentration in BIFs of the Geraldton mining camp. This is a collaboration with Peter Hollings from Lakehead University.

This research on sediment-hosted gold has resulted in a new genetic model for Carlin Type and orogenic gold deposits, which has major relevance for mineral exploration. Ross Large presented keynote talks on this topic at the Goldschmidt Conference in Knoxville and International Mineralogical Association Conference in Budapest.

P3B3A
SHALES AND CARBONATES - IMPROVED VECTORS FOR ROSEBERY AND HERCULES STYLE VHMS

Leaders /
Andrew McNeill, Bruce Gemmell

Exploration for VHMS deposits in the Mt Read Volcanics (MRV) is based on the concepts that all economic mineralisation occurs at a particular time horizon and this horizon has been adequately tested to a depth of 150-200 m. Therefore, from the exploration perspective, it is important to define the location and down-dip extent of the prospective horizon and to locate alteration envelopes that may be associated with VHMS mineralisation.

In the past year, work has focused on developing a detailed understanding the Tl and Sb 'envelope' around the Rosebery and Hercules ore bodies. Results indicate that although the contents of primitive pyrites and galena may have elevated, to 100s ppm Tl, the bulk of the Tl (>85-99%) is hosted by phyllosilicates. Furthermore, mass balance calculations suggest that, in contrast to some other hydrothermal systems, the Tl contents of K-feldspars in the Rosebery system are negligible.

P3B5A
THE TWEEFONTEIN SECTOR OF THE PLATREEF, SOUTH AFRICA

Leader /
Jeff Foster

Team Member /
Dave Hutchinson

This industry-sponsored project was designed to investigate the mechanisms and processes that led to the formation of Ni-Cu-Platinum Group Element (PGE) mineralisation in the Tweefontein Sector of the Platreef, northern limb of the Bushveld Complex, South Africa.

Two field seasons have been completed with the aim of examining drill core (logging), and collecting samples for geochemical analysis and detailed petrological work. The geochemical data revealed the presence of recognisable zones that can be traced across adjacent drill holes. These zones correlate with features observed in thin-sections, and SEM observations for the location, distribution and identification of platinum-bearing minerals. Microprobe analyses of the main minerals further support the presence of broadly defined zones that can be traced from hole to hole. These broad zones define intrusive 'packages' with varying degrees of metamorphic and metasomatic overprinting, together with a unit that appears to host a large number of altered ultramafic xenoliths. The overprinting event resulted in modification of the original host rock and the sulfide-PGE assemblages contained within it.

Comparison of cores across the area of interest has led to a new understanding of the construction and genesis of the Platreef.

P3B5B
THE CHARACTERISATION OF MAGMATIC SULFIDE SYSTEMS

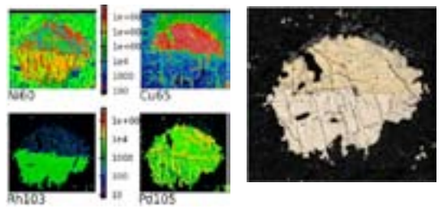
Leader /
Jeff Foster

Team Member /
Dave Hutchinson

The principal aim is to investigate the mechanisms and processes that lead to the formation of Ni-Cu-Platinum Group Element (PGE) mineralisation. A sample encompassing the main mineralised portion of the Merensky Reef has been studied in detail together with samples from the Platreef (both part of the Bushveld Complex, South Africa), plus samples of disseminated, globular and massive ore from Noril'sk-Talnakh, Russia.

Many models and mechanisms have been proposed to explain the formation of the Merensky Reef. However, most have focused on a limited number of aspects in what now appears to have been a complex ore forming system. CODES' research has confirmed the presence of multiple chromitite layers along the contact to the footwall rocks that, together, appear to form a single layer. A number of petrologically distinctive zones, on a mm to cm scale, can be recognised, and each hosts a distinctive sulfide and platinum group mineral assemblage.

Pt and Pd are expected to behave similarly and, together with the other PGEs (Os, Ir, Ru & Rh), reside in one or other of the sulfide mineral phases. LA-ICP-MS mapping has consistently revealed the presence of all PGEs, except Pt, from the Merensky and Platreef samples. Pt does not appear to be hosted within the sulfides. Conversely, Pt is present in some, but not all, of the sulfides in different portions of the Noril'sk-Talnakh intrusions. This part of the study shows there are significant problems with the current understanding of the behaviour of these elements. In the Merensky Reef, Pt-minerals are abundant and spatially associated with sulfides throughout the chromitite and overlying silicate portions. Likewise, Pt-minerals are spatially associated with sulfides in the Platreef and Noril'sk-Talnakh samples. The new observations cannot adequately be explained by current models for the formation of the Merensky Reef and other Ni-Cu-PGE ore-bearing systems. Consequently, new models have been devised that more accurately fit these new and unexpected observations. The cumulative evidence for the Bushveld strongly supports multi-stage processes where magmas ponded in one or more staging chambers en-route to the crust. In the case of the Merensky, the main mineralising events involved sedimentary-style mechanical processes that resulted in the deposition of chromites, sulfides and platinum-mineral grains under magmatic conditions.



LEFT: LA-ICP-MS IMAGES OF THE DROPLET SHOWING THAT THE Rh IS CONCENTRATED IN THE PYRRHOTITE, AND Pd IS ASSOCIATED WITH THE PENTLANDITE - IMAGES SUCH AS THESE ARE LEADING TO AN IMPROVED APPRECIATION OF THE DISTRIBUTION OF THE ECONOMICALLY SIGNIFICANT PGEs IN SULFIDE ORES, WHICH HAS IMPLICATIONS FOR THEIR GENESIS AND RECOVERY. **RIGHT:** AN 11MM DIAMETER IMMISCIBLE SULFIDE DROPLET FROM THE NORIL'SK DEPOSIT, COMPOSED OF CHALCOPYRITE, PENTLANDITE AND PYRRHOTITE (REFLECTED LIGHT IMAGE).

P3B5C
THE GEOLOGY, GEOCHEMISTRY AND GENESIS OF THE AVEBURY Ni DEPOSIT – IMPLICATIONS FOR EXPLORATION

Leader /
Jeff Foster

Team Members /
Tony Crawford, Dave Hutchinson, Vadim Kamenetsky

Student /
Alexey Lygin

The Avebury nickel sulfide deposit is hosted by serpentinised ultramafic rocks of the McIvor Hill ultramafic complex, western Tasmania. This complex is one of 15 mapped Cambrian ultramafic complexes found within metasediments of the Crimson Creek Formation. The deposit was discovered by CRA in 1997 and further developed by Allegiance Mining NL.

Major and trace element compositions (from LA-ICP-MS, in both spot and mapping modes) of sulfide minerals and chrome spinels, coupled with whole-rock major and trace elements, including chalcophile-element geochemistry, indicate that Avebury is an economically significant example of a hydrothermal Ni sulfide deposit in ultramafic rocks, characterised by low Cu and PGE and enriched in the 'granite' related elements W, U, Pb, Bi, Mo, Sn, Sb and Au.

A preliminary interpretation is that the deposit was formed largely as a result of metasomatic processes related to the intrusion of the Middle Devonian Heemskirk granite, and that there is no evidence of the remobilisation of pre-existing Ni-mineralisation as part of this process.

P3B6A
STRUCTURE AND FORMATION OF THE SAVAGE RIVER MAGNETITE DEPOSIT

Leader /
Tony Webster

Team Member /
Ron Berry

Student /
Victoria Braniff

Collaborators /
Ralph Bottrill, Jafar Taheri

After 45 years of mining, the geology of the Savage River magnetite deposit is still very poorly understood, despite it being the largest metalliferous deposit in Tasmania. With the support of Grange Resources, a project was developed with the primary aim of understanding the structure of the highly strained rocks at the mine, and the application of this knowledge to problems of slope stability management, resource definition and near-mine exploration.

Key findings, to date, include:

» The main host assemblage and adjacent, less deformed, Oonah Formation metasediments preserve extensive evidence of all phases of the deformation and metamorphism recognised in the Arthur Lineament. Despite the very high strain, bedding is well-preserved in most of the important rock packages of the mine area.

» Models, developed using Leapfrog software, have revealed that the internal structure of the North Lens is composed of several shallow, southerly-plunging pipe-like shoots (folds) within a lower-grade halo. The shoots preserve the remnants of iron-rich layers formed in high-magnesium sediments and metamorphosed to serpentine and magnetite during deep burial.

» Ore textures indicate that all magnetite is metamorphic and mostly formed pre-CaD2 (Cambrian deformation), with continued formation syn- and post- CaD2. The ore lenses have the same deformational history as their wall rocks, and the present geometry of the ore bodies is the result of tectonic processes. The magnetite ores were not formed by post-tectonic replacement.

» The generally low temperature, brittle and unhealed Devonian structures have had the most impact on the geotechnical properties of the pit wall rocks.

P3B7A
IRON OXIDE COPPER-GOLD AND RELATED DEPOSIT TYPES

Leader /
Stuart Bull

Team Members /
Garry Davidson, Sebastien Meffre

Collaborators /
Mark Allen, Jorge Benavides, Hamish Freeman

A new research project on the volcano-sedimentary and chrono-stratigraphic architecture of the host rock succession at Prominent Hill commenced during the year. The aims are to:

» Confirm the broad scale volcano-sedimentary architecture/ environments of the host rock succession by graphic core logging, with follow-up petrographic analysis of key samples.

» Test the viability of using LA-ICP-MS analysis of U-bearing phases within this framework to establish a provisional chrono-stratigraphy.

Although the details of the project outcomes remain confidential to OZ Minerals, it can be reported that a basin framework for the mineralised interval has been constructed by integrating the sedimentary facies analysis and chrono-stratigraphic data. This framework differs substantially from what has previously been published, and has implications for both near mine and regional exploration.

Outlook /

» Secure funding and commence AMIRA P1060 – Enhanced Geochemical Targeting in Magmatic-Hydrothermal Systems.

» Secure funding and commence AMIRA P1031 – Copper, Uranium, and Precious Metals in Oxidising Sedimentary Basins: Ore Formation and Location.

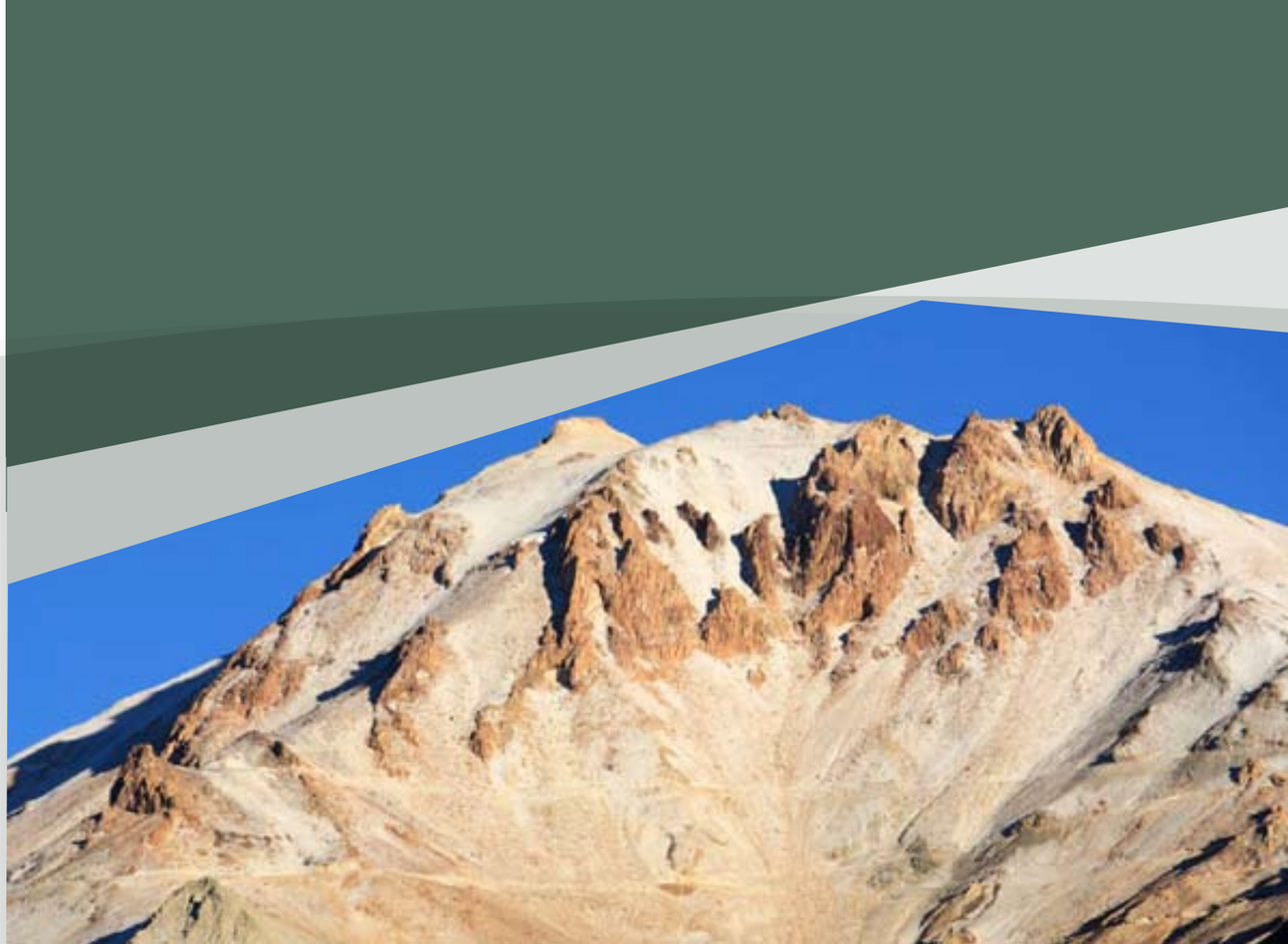
» Commence project to investigate the application of near-mine ambient seismic methods to brownfields mineral exploration and in-mine seismic rock mass characterisation.

» Develop computing techniques focussing on spatial data structures.

» Expand studies at Savage River to encompass a geological interpretation of the Centre Pit and South Pit deposits.

» Hugo Galvan, Lindsey Clark and Bronto Sutopo to complete PhD theses.

» New post-doctoral study at Gosowong will switch the research focus from landscape to drainage, and develop new techniques for the identification of potentially mineralised structures in underlying bedrock.



Program Four /

RECOVERY

Objective /

To create and develop a series of small-scale, low-cost practical geometallurgical tools, protocols, proxies and processing indices for the purpose of ore-body domaining and whole mine optimisation.

Introduction /

Geometallurgy is an exciting, cross-disciplinary activity that is having a significant economic impact on the mining industry. The ability to create and calibrate a geometallurgical 'toolkit' for an ore deposit at different stages in its life cycle leads to improved decision making and early recognition of processing options.

The three broad variables that control the economic viability and performance of an ore deposit are the amount of CAPEX required to put a deposit into production; cost per unit metal produced, net of by-products and co-products (C1 costs); and metals pricing. Of these variables, only CAPEX and C1 costs can be controlled.

The geometallurgical approach developed in AMIRA P843 and P843A utilises calibrated, small-scale tests to create proxies, which are used to define optimal processing domains within an economic envelope. The definition of an economic envelope is directly related to the conversion of resources to reserves, based on a series of modifying factors as defined by the JORC code or equivalent. This early detailed understanding of an ore body represents a significant leap forward from previous methods, which often relied on statistically insignificant bulk tests within a resource, defined on the basis of conventional grade-tonnage distribution.

The geometallurgical approach can be applied at a number of stages in the development of a mine, with maximum returns generated in relation to feasibility studies that precede development of new ore bodies or major expansions. The continuous application of geometallurgical protocols to extant ore bodies leads to performance optimisation and reduced C1 costs. The combination of reduced C1 costs and optimised CAPEX leads to superior economic performance.

The six principal themes of P843A, coupled with the case-study modules, effectively cover many of the major risk areas of mining and minerals recovery. Furthermore, the combined presence of Themes 1, 2 and 5 greatly enhances the probability of optimal cost curve solutions. As we move into a future further constrained by ever-rising energy and environmental costs, recognition of processing domains and routes can be used to more accurately and reliably establish the reserve base and, therefore, the amount of CAPEX required for a specific production rate.

Leader /
Jeff Foster

Team Members /
Ron Berry, Julie Hunt, Maya Kamenetsky, Andrew McNeill
CSIRO – Byron Benvie, Nicole Botsis, Goutam Das, Matthew Jeffrey, Dave Kelly, Nick Kelly, Laura Kuhar, Dave Robinson, Nicole Turner
UQ – Dee Bradshaw, Alan Bye, Alan Cocker, Mansour Edraki, Toni Kojovic, Angus McFarlane, Simon Michaux, Khoi Nguyen, Barry Noller, Italo Onederra, Pat Walters, Steve Walters

PhD Students /
Natalee Bonnici, Anita Parbhakar-Fox, Adel Vatandoost
UQ – Mitesh Chauhan, Cathy Evans, Luke Keeney, Hector Parra, Kevin Pietersen

Highlights /

Theme 1 – Predictive Environmental Indices

» Bernd Lottermoser appointed as Professor in Environmental Geochemistry under the UTAS New Stars program. Bernd will join the team in January 2011.

» Preliminary results from long-term column leach experiments are encouraging.

Theme 2 – Integrated Blast Modelling

» A new tool developed (iFragX) that creates links between blastability and geometallurgical domains defined by the DomAIn software.

Theme 3 – Deterministic Comminution Modelling

» Introduction of a simple power meter during Ci crushing has shown a consistent improvement in the A*b prediction, particularly in the case of harder samples. This evaluation also confirmed the utility of the A*b Express test as a rapid means of quantifying the impact resistance of core samples, using only one test at a single low RBT energy.

Theme 4 – Texture-based Liberation and Recovery Modelling

» The Julius Kruttschnitt Mineral Separability Index (JKMSI) test is being further investigated as a potential method to obtain information on flotation variability.

» Software developed to simulate textures found within rocks.

» Research from a test site indicates the analysis of mineral maps is a viable way of rapidly and inexpensively producing data that can be used to rank samples for liberation potential, and hence recovery.

Theme 5 – Predictive Leaching Indices

» New, small-scale approach for determining relative sample rheology, using compressive yield stress measurements, has been applied to samples from a calcrete-hosted uranium deposit with promising outcomes.

» Agglomeration of a standard ore and a variety of ore blends has established confidence levels for repeat tests, and identified pellet porosity and moisture content as key variables affecting agglomerate strength.

» Completion of development and initial testing of the 'overview level' diagnostic leach methodology.

» Preliminary copper sulfide speciation leaching protocol determined for analysis of chalcocite, covellite, chalcopyrite and bornite.

» Texture-based leaching simulation method updated to incorporate specific mineral leaching rates and compared with a 'simple' dissolution test data.

» Prototype synthetic samples produced for blast-to-leach test work.

Theme 6 – Specialist Analytical and Software Support

» Two software applications suitable for generating more value from core imaging are in development, with STORC being close to release.

Case Studies and Technology Transfer

» Final scoping completed for 11 of the 12 sites nominated by sponsors, leading to submission of a fully costed proposal. Five case studies have commenced.

Core Projects /

Project P4A (AMIRA P843A) – GeM^{III} Geometallurgical Mapping and Mine Modelling – is split into the following six themes, plus a sub-project covering case studies.

Theme 1 Predictive environmental indices

Theme 2 Integrated blast modelling

Theme 3 Deterministic comminution modelling

Theme 4 Texture-based liberation and recovery modelling

Theme 5 Predictive leaching indices

Theme 6 Specialist analytical and software support

Case Studies and Technology Transfer

Project Summaries /

P4A1
PREDICTIVE ENVIRONMENTAL INDICES

Leader /
Mansour Edraki

Team Members /
Ron Berry, Barry Noller, Steve Walters

Student /
Anita Parbhakar–Fox

Mineralogical and textural data can be combined with geochemical assays for more realistic characterisation of rocks in regard to acid generation, particularly at the very early stages of the mine life cycle. Samples from an abandoned Au mine in Queensland were subject to an ongoing column leaching experiment, and mineral surface analysis (MLA-SEM and LA-ICP-MS) supports the geochemistry-mineralogy-texture (GMT) approach to environmental rock characterisation. The kinetic test results broadly follow the mineralogy and the onset of acid generation is correctly predicted, which would not be possible with static leach tests. The element concentrations in leachates, although at very low levels (ppb), are also consistent with the mineralogy. The combination of element and mineral mapping results shows an emerging pattern that could be used to predict the release of deleterious elements based on the solubility of host minerals. For example, primary pyrite mineral grains have a core enriched in Au and As and are surrounded with secondary sulfates and iron oxyhydroxides with high Ni and Co content.

Professor Bernd Lottermoser was appointed late in the year under the UTAS New Stars program. He will join the team in January 2011 and will take a leading role in the further development of Theme 1.

P4A2
INTEGRATED BLAST MODELLING

Leaders /
Italo Onederra, Simon Michaux

Team Members /
Ron Berry, Alan Cocker, Toni Kojovic, Steve Walters

Student /
Hector Parra

The overall aim is to generate spatially-located, post-blast, run-of-mine (ROM) size distributions in a mine planning and GeM^{III} context. The project will integrate measurements of bulk rock properties into advanced blast fragmentation models, using technologies and procedures developed in the initial P843 project. This will provide more appropriate inputs into advanced comminution and leaching performance models.

The potential interaction between the current iFrag modelling framework and sources of spatially-resolved data has been explored. At this stage, the focus has been on exploring the use of Measure While Drilling (MWD) data. To distinguish logical rock units on the basis of blastability in the MWD data, a variant of the DomAIn software being developed within GeM^{III} was evaluated and subsequently linked to the iFrag interface. This extension is undergoing further development and testing, and validation will continue over the next six months. In addition, further evaluation of the Blastability Index and proxy-based data inputs will continue in 2011.

P4A3
DETERMINISTIC COMMINUTION MODELLING

Leader /
Toni Kojovic

Team Members /
Julie Hunt, Simon Michaux, Pat Walters, Steve Walters

Students /
Luke Keeney, Adel Vatandoost

In 2010, the team has been involved in technology transfer activities with JKTech, providing support to its new Sumner Park facility, which aims to offer sponsors access to GeM^{III} tests as part of the case studies. The work at Sumner Park has integrated further development of Theme 3 topics, while providing training using over 100 intervals of intact NQ and HQ diamond drill core from two significant Australian ore deposits.

Two principal outcomes have been achieved. The first is the continuation of the Ci power meter evaluation, following the preliminary trials using jet black granite slabs, which indicated the specific energy required to crush the samples could be used to estimate the A*b index. Recent work focused on a selection of 138 samples with a wide range of impact hardness, sourced from two significant Australian Cu–Au deposits, and select development materials.

The second area of investigation looked at the potential use of modelling to quantify the blend response of AG and SAG mills when treating two ore components with different impact resistance, or A*b hardness indices. The approach is based on a conceptualised model of the AG/SAG process, calibrated to a set milling configuration and blend of ore types of known hardness. The model can then be applied to estimate the response to other blends of the same ore types in a given mill configuration.

P4A4
TEXTURE–BASED LIBERATION AND RECOVERY MODELLING

Leader /
Dee Bradshaw

Team Members /
Ron Berry, Julie Hunt, Maya Kamenetsky, Khoi Nguyen, Steve Walters

Students /
Natalee Bonnici, Mitesh Chauhan, Cathy Evans, Kevin Pietersen

The focus is on developing an appropriate methodology to populate deposit block models with recovery predictions that incorporate inherent geological variability. For this to be effective, it is necessary to understand and characterise the contribution of mineral texture and composition on the breakage and separation of ore minerals during floatation. Several research streams are being investigated in order to achieve this objective

The major part of an Australian-based case study falls within this Theme. This study is developing a recovery predictor for the block model, using an appropriate small-scale test that has potential applications in various projects. Phase I test-work at JKMRC is complete and will be assessed in parallel with the mineralogical characterisation obtained from MLA analysis. This phase compared the response of 24 ores to JKMSI and batch flotation tests. Phase II, mineralogical characterisation, is approximately two-thirds complete.

An error model has been developed to identify the number of repeat tests required for a particular sample. The equipment and methodology used for the test are being developed outside the GeM^{III} project, at JKMRC. However, its application to geometallurgical characterisation is being developed within the project as part of Mitesh Chauhan's PhD study. Using samples from an Australian Cu-Au deposit, a preliminary protocol has been created that links batch flotation test recoveries to JKMSI recoveries. This includes models based on mass and Cu recoveries, and compensates for the error associated with these models. An analysis is also being carried out to determine relationships between mineralogy and JKMSI recoveries.

PhD student, Kevin Pietersen, has developed a set of tools to compare a range of image types (raw, processed, and sub-sampled). A tool to create texture has been completed. A key project aim is to design a comprehensive experiment linking image processing and image analysis. A combination of artificial and natural rock textures will be used to evaluate the Phase 1 tools.

P4A5
PREDICTIVE LEACHING INDICES

Leaders /
Dave Robinson, Matthew Jeffrey

Team Members /
Byron Benvie, Nicole Botsis, Goutam Das, Dave Kelly, Nick Kelly, Laura Kuhar, Nicole Turner, Angus McFarlane

Researchers at the Parker Centre are responsible for the development of predictive leaching indices within GeM[III].

Key outcomes included:

» The new proposed small-scale approach for determining relative sample rheology, using compressive yield stress measurements, has been applied to samples from a calcrete-hosted uranium deposit in Western Australia with promising outcomes.

» Agglomeration of a standard ore and a variety of ore blends has established confidence levels for repeat tests, and identified pellet porosity and moisture content as key variables affecting agglomerate strength.

» Completion of development and initial testing of the 'overview level' diagnostic leach methodology.

» Determination of a preliminary copper sulfide speciation leaching protocol for analysis of chalcocite, covellite, chalcopyrite and bornite.

» The texture-based leaching simulation method has been updated to incorporate specific mineral leaching rates and compared with 'simple' dissolution test data.

» Prototype synthetic samples have been produced for blast-to-leach test work. These samples are being tested by the JKMRC/BRC for strength and preliminary blasting response. They will then be leached to determine copper recovery and homogeneity.

P4A6
SPECIALIST ANALYTICAL AND SOFTWARE SUPPORT

Leader /
Ron Berry

Team Members /
Alan Bye, Maya Kamenetsky, Khoi Nguyen, Steve Walters

Key activities included:

» The development of several improved methods and protocols for core imaging.

» Two software packages capable of extracting more value from core imaging are in development, with STORC being close to release.

» The ioGeM developments are mature, and a method for handling noisy geometallurgical data (DomAIn) is at an advanced stage.

» New micro-analytical trace element mapping will increase in line with demand from the case studies.

P4A7
CASE STUDIES AND TECHNOLOGY TRANSFER

Leader /
Steve Walters

Team Members /
Ron Berry, Dee Bradshaw, Alan Bye, Julie Hunt, Toni Kojovic, Angus McFarlane, Andrew McNeill

Elective case studies are a significant aspect of P843A. These are designed to take outcomes, mainly from the earlier P843 project, and apply them to focussed, site-based applications as part of validation and technology transfer.

Twelve sites were nominated by sponsors for case study scoping in the current round. This involved close consultation between the researchers and nominated sites to identify specific high impact areas that could be used to validate tools and methodologies. Final scoping has been completed for 11 of the sites, leading to submission of a fully costed proposal. This involves itemised work programs and agreed outcomes based on individually costed items. Five case studies have commenced and are at various stages of completion. Sign-off is awaited for five other case studies, while one case study is unlikely to proceed. Scoping is continuing for the remaining nominated site.

It is envisaged that other case studies could be developed in the second half of P843A to validate new outcomes for the project.

Outlook /

» Develop a research team around Bernd Lottermoser, with a focus on environmental indices.

» Improve quality and understanding of inputs into iFragX, with the aim of developing robust, domain-based, blast-to-sort models.

» Continue to develop GeMCi and A*b indices through a combination of core research and case studies.

» Attract a postdoctoral research fellow to accelerate small scale physical flotation testing and texture based modelling.

» Select a case study site to trial the diagnostic leach protocol.

» Expand capabilities in dump and heap leach, fluid-flow and metal liberation modelling.

» Create sequential and simultaneous analytical functions in DomAIn software.

» Investigate alternate models for the development of SimLeach.

Program Five /

TECHNOLOGY

Objective /

Research activities within the Program are aimed at developing new analytical techniques, ensuring that research is driven by innovative technology, and the Centre is at the cutting edge of analytical developments of relevance to ore deposit research.

The program also aims to provide CODES' research staff and students with access to state-of-the-art micro-analytical equipment within Australia and overseas, and maintain their awareness of new analytical developments.

Introduction /

The Technology Program explores and develops novel analytical and data interpretation techniques based on the latest technological developments, such as a number of high spatial resolution microprobes. This helps in the understanding, exploration and exploitation of deep earth resources.

Current research projects focus mainly on expanding the capabilities of in-situ multi-element analysis by laser ablation (LA), inductively-coupled plasma mass-spectrometry (ICP-MS), in-situ isotope analysis by LA multi-collector (MC) ICP-MS, non-destructive multi-element analysis using nuclear (PIXE) and synchrotron-based X-ray microprobes (XFM), and development of new stable-isotope solution-based analytical techniques. Research activities also develop data interpretation tools, such as new algorithms and new user-friendly scientific software packages. These are used primarily for modelling the deep earth processes that lead to ore formation, and processing of analytical data. Many of the projects include close collaborations with Node partners, such as the University of Melbourne, CSIRO and the Australian National University.

Highlights /

» New urananite and sphene standards were developed for U-Pb dating of these minerals, leading to significant improvements in accuracy of their age determinations.

» Development of a new technique for creating images from LA-ICP-MS data that enables researchers to analyse irregularly shaped domains, and merge these results with sample images to display the data in a precise spatial context.

» Development of a mapping technique for Large-scale Electric Field Distribution in sulfide minerals.

» Development of Hyper-spectral Ionoluminescence analysis mapping on the CSIRO nuclear microprobe.

» The first XANES mapping experiments were performed on the XFM beamline using Maia-384 detector, looking at As and Fe redox state and chemical speciation.

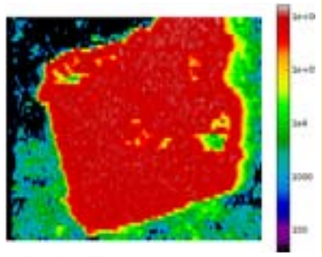
Leader /
Leonid Danyushevsky

Team Members /
Stacey Borg, David Cooke, Garry Davidson, Sandrin Feig, Karsten Goemann, Marcel Guillong, Janet Hergt, Jamie Laird, Sebastien Meffre, Bence Paul, Anya Reading, Chris Ryan, Clara Wilkinson, Jamie Wilkinson, Jon Woodhead

PhD Students /
Kirill Bychkov, Sarah Gilbert, Dan Gregory

Masters Student /
Sid Paleri (UMelb)

Collaborators /
AGILENT – Fred Fryer, Naoki Sugiyama
AUSTRALIAN SYNCHROTRON – Martin de Jonge, Daryl Howard, David Paterson
BHP BILLITON – Kathy Ehrig
BROOKHAVEN NATIONAL LABORATORY, USA – Gianluigi De Geronimo, Tony Kuczewski, Peter Siddons
CSIRO – James Cleverly, Paul Dunn, Steve Fraser, Rob Hough, Murray Jensen, Robin Kirkham, Weihua Liu, Gareth Moorhead
ETH ZURICH, SWITZERLAND – Jung Hun Seo, Markus Waelle
GEOSCIENCE AUSTRALIA – Terry Mernagh, Bill Papas
INSTITUT NEEL AND EUROPEAN SYNCHROTRON RADIATION FACILITY, FRANCE – Jean-Louis Hazemann, Denis Testemale
LAURIN TECHNIC – Michael Shelley
MONASH UNIVERSITY – Massimo Raveggi
MOSCOW STATE UNIVERSITY, RUSSIA – Pavel Plechov
NATIONAL OCEANOGRAPHY CENTRE, UK – Darryl Green
UNIVERSIDADE FEDERAL MINAS GERAIS, BRAZIL – Rosa Figueiredo e Silva
UNIVERSITY OF ADELAIDE – Joel Brugger, Barbara Etschmann
UNIVERSITY OF BERN, SWITZERLAND – Thomas Pettke
UNIVERSITY OF BRITISH COLUMBIA, CANADA – Rich Friedman
UNIVERSITY OF MELBOURNE – Brett Johnson, Roland Maas, Jeff McCallum
UNIVERSITY OF WESTERN AUSTRALIA – Steffen Hagemann
WOODS HOLE OCEANOGRAPHIC INSTITUTION, USA – Chris German



Core Projects /

Theme 5A – Advancing Spatially Resolved Mass Spectrometry

P5A1 LA-Q-ICP-MS analysis development

P5A2 New LA-Q-ICP-MS applications

P5A3 New LA-MC-ICP-MS applications

P5A4 New stable isotope MS applications

P5A4A Cracking the sulfate isotopic composition problem in ancient hydrothermal systems: application of the Carbonate-Associated Sulfate (CAS) method

Theme 5B – Advancing Non-Destructive Focused-Beam Spectroscopy

P5B1 Ion beam analysis development

P5B2 New ion beam applications

P5B2A Improved quantification of PIXE analyses of fluid inclusions using internal standardisation and accurate volumetric determination

P5B3 Synchrotron X-ray probe development

P5B4 New synchrotron-based applications

Theme 5C – Data Interpretation Tools

P5C2 Improved image processing algorithms for LA-ICP-MS

P5C3 Modelling of crystallisation and melting processes

THE ABOVE LIST REPRESENTS ACTIVE PROJECTS IN 2010

Project Summaries /

P5A1
LA-Q-ICP-MS ANALYSIS DEVELOPMENT

Leaders /
Sebastien Meffre, Leonid Danyushevsky

Team Member /
Marcel Guillong

Students /
Sarah Gilbert, Dan Gregory

Collaborators /
Fred Fryer, Terry Mernagh, Bill Papas, Michael Shelley, Naoki Sugiyama

This project designs and develops new instrumentation to ensure continuing advances in geological LA-Q-ICP-MS applications. Example developments include ablation cells, the interface between the laser and the mass-spectrometer, and testing new types of laser microprobes and mass-spectrometers.

The focus during the year was on improving the sensitivity, reliability and versatility of the LA-ICP-MS instrumental set-ups at the CODES analytical facility. Activities included:

» An optimal combination of the three laser microprobes and three mass-spectrometers was determined, which maximises the effectiveness of the facility and the quality of the output.

» The performance of the new collision cell design, installed in the Agilent 7700x mass-spectrometer, was assessed for a range of laser ablation and bulk solution applications. Collision cell technology was found to provide significant benefits for in-situ measurements of S isotopic compositions in sulfides by LA-ICP-MS, and for bulk solution ICP-MS of geological samples.

» FEP (fluorinated ethylene propylene) tubing was found to be superior when various types of plastic tubing were tested for their suitability as an interface between the laser-probe and the mass-spectrometer in relation to minimising background levels and instrument drift. It was demonstrated that instrument drift is largely related to absorbed air and moisture on the surfaces of the samples, ablation cells and the interface tubing.

» Significant improvement to the software and hardware of the Resolution M50 laser probe was achieved - in close co-operation with the manufacturers (Laurin Technic and Resonetics).

P5A2
NEW LA-Q-ICP-MS APPLICATIONS

Leaders /
Marcel Guillong, Leonid Danyushevsky

Team Member /
Sebastien Meffre

Student /
Sarah Gilbert

Collaborators /
Kathy Ehrig, Rich Friedman, Jung Hun Seo, Roland Maas, Thomas Pettke, Massimo Raveggi, Markus Waelle

New geological LA-Q-ICP-MS applications are being developed in the fields of ore deposit geology, igneous petrology, hydrothermal fluid chemistry and U-Pb dating of zircons and other minerals.

The main outcomes in the past year were:

» The ablation cell design for the Resolution M50 Laser Microprobe resulted in less than 2% error over the entire ablation space of the cell, thus allowing for development of highly accurate LA-ICP-MS applications.

» Using the Resolution M50 Laser Microprobe, the detection limits in the single digits ppt region were achievable with a laser beam size of 380 microns, opening opportunities for in-situ determination of ultra-low elemental concentrations in minerals.

» The levels and mechanism of argide species production by different model mass-spectrometers were investigated and it was concluded that the main influence is the design of the interface region behind the skimmer cone. Argide production is the lowest when the pressure in the interface is high due to restricted Ar flow. Understanding the behaviour of argides is important for accurate in-situ analysis of light PGE (Ru, Pd, Rh) in sulfide minerals, as they are subject to base-metal argide interferences.

» Depth-dependent element fractionation was demonstrated in the analysis of fluid inclusions in quartz. Work has begun on quantifying this effect to assess its impact on the accuracy of fluid inclusion analysis. A good agreement was established between ablation of liquid and solid SRMs using the Resolution M50 Laser Microprobe. This will allow for a simplified analytical protocol for fluid inclusion analysis by LA-ICP-MS.

» New urananite and sphene standards were developed for U-Pb dating of these minerals, leading to significant improvements in accuracy of their age determinations.

» Using a mixture of Xe and He gases as a medium within the collision cell of Agilent 7700x ICP-MS has led to significant improvements in accuracy of in-situ S isotopic measurements. A method for precise in-situ S isotopic analysis by LA-ICP-MS is now under development.

P5A3
NEW LA-MC-ICP-MS APPLICATIONS

Leaders /
Bence Paul, Janet Hergt

Team Members /
Leonid Danyushevsky, Sebastien Meffre, Jon Woodhead

New analytical techniques are being developed for quantitative, in-situ analysis and the imaging of isotopic compositions of key elements in a range of geological materials. This will provide new spatially resolved information to help unravel processes involved in ore formation.

Further in-situ Pb isotope work on pyrite was conducted; however, the most important new advance was the development of a new technique for creating images from LA-ICP-MS data according to the x,y position in the laser cell, rather than time (as is the case with existing protocols). Instead of being restricted to rectangular domains, this new approach allows images to be created from irregular shapes and enables the analyst to follow non-linear features (e.g. crystal growth zones). This also allows laser ablation results to be merged with referenced images of the sample, illustrating the analytical results in a precise spatial context.

P5A4
NEW STABLE ISOTOPE MS APPLICATIONS

Leaders /
Janet Hergt, Bence Paul

Team Members /
Leonid Danyushevsky, Sebastien Meffre, Jon Woodhead

Student /
Sid Paleri

Collaborators /
Chris German, Darryl Green

The aim is to develop new analytical protocols for the measurement of non-conventional stable isotope compositions (e.g., Cu, Mo) that can be used to explore ore forming processes.

Progress includes the re-development of robust Cu separation protocols that can be applied to a broad range of geological matrices (e.g., to sulfide and silicate samples). This technique has been tested using in-house reference materials and demonstrated to generate data that is similar or higher in quality compared to data produced by other laboratories, worldwide. The method is currently being applied to hydrothermal sediment samples from the Rainbow vent field on the Mid-Atlantic Ridge, as part of an MSc project conducted by Sid Paleri.

Protocols for molybdenum isotope analysis have also progressed using reference materials supplied from other laboratories, including those at Bristol, Bern and Curtin universities. An isotope spike has been prepared and characterised to facilitate the precise analysis of sample solutions. Preliminary work has commenced on molybdenite ore samples.

P5A4A
CRACKING THE SULFATE ISOTOPIC COMPOSITION PROBLEM IN ANCIENT HYDROTHERMAL SYSTEMS: APPLICATION OF THE CARBONATE-ASSOCIATED SULFATE (CAS) METHOD

Leader /
Garry Davidson

Team Members /
David Cooke, Sandrin Feig, Janet Hergt

Collaborators /
Rosa Figueiredo e Silva, Steffen Hagemann

This project evaluates the use of carbonate-hosted sulfate as a tool for determining the composition of oxidised sulfur in ore systems, where no sulfate minerals are available. The substitution of SO_4 into carbonate has been well established for sedimentary carbonates, but the levels that substitute into hydrothermal carbonates are far lower (commonly <100 ppm). Modern beam-based isotopic measurement techniques cannot determine the isotopic composition of sulfate at such low concentrations. Furthermore, use of elemental analysers, which are increasingly being adopted for whole-rock sulfur determination, is not useful for samples with several forms of sulfur (i.e., sulfide, sulfates, etc). Consequently, an important objective is to refine a chemical means of extracting and measuring the isotopic composition of carbonate-hosted sulfur at low levels.

The extraction facility was moved and refurbished during 2010, which took most of the year. However, the facility is now complete and ready for substantial activity in 2011.

P5B1
ION BEAM ANALYSIS DEVELOPMENT

Leader /
Jamie Laird

Team Members /
Chris Ryan, Stacey Borg

Collaborators /
Brett Johnson, Jeff McCallum

The aim is to better understand the role of metal sulfide semiconductivity on the deposition of precious metals, such as gold. The major outcome of the work this year was the completion of the technique for laser mapping of electric fields in sulfides, and its illustration on pyrite, galena and chalcopyrite assemblages. This is an important step in correlating growth with surface properties and, in particular, the role of defects and impurities. In parallel with this research, the Scanning Electrochemical Microscope is nearing completion and will provide the means to directly grow gold on the regions characterised by high electric fields, as identified by the laser mapping technique.

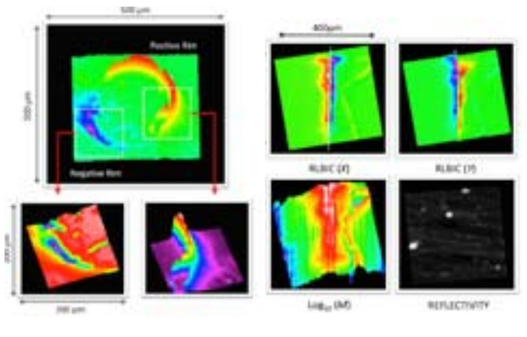
P5B2
NEW ION BEAM APPLICATIONS

Leader /
Jamie Laird

Team Members /
Chris Ryan, Jamie Wilkinson

The aim is to introduce new ion beam techniques developed by the community to better characterise geological materials, in particular fluid inclusions.

The major outcome was the completion and illustration of Hyperspectral Ionoluminescence mapping on the CSIRO nuclear microprobe. Maps of intrinsic defects in epidote and quartz have been collected and correlated with similar measurements made with cathodoluminescence (CL). The method, when combined with PIXE analysis, allows both elemental and chemical information to be extracted simultaneously when performing fluid inclusion analysis.



FIELD DISTRIBUTION WITHIN (A) NATURAL PYRITE WITH SYNTHETIC JUNCTION FORMED BY Au DEPOSITION AND (B) AN LBIC IMAGE (VARIOUS COMPONENTS) OF A DISLOCATION IN GALENA.

P5B2A
IMPROVED QUANTIFICATION OF PIXE ANALYSES OF FLUID INCLUSIONS USING INTERNAL STANDARDISATION AND ACCURATE VOLUMETRIC DETERMINATION

Leader /
Jamie Wilkinson

Team Members /
Leonid Danyushevsky, Marcel Guillong, Jamie Laird, Chris Ryan, Clara Wilkinson

Student /
Sarah Gilbert

PIXE data acquisition was completed for three principal sample sets: synthetic fluid inclusions, natural halite-saturated inclusions from the San Pedro porphyry-skarn deposit, New Mexico, and dilute CO_2-bearing inclusions from the Butte porphyry Cu-Mo deposit, Montana.

Comparison of the San Pedro data between LA-ICP-MS analysis and PIXE shows that there are marked inclusion depth- and mass-dependent deviations in the PIXE, resulting from an imperfect correction for inclusion geometry and depth effects. Modelling depth effects shows that current data reduction protocol underestimates light elements (Cl, K) at shallow depths (less than ~20 microns), and overestimates them at greater depths in an approximately exponential relationship. For intermediate masses (e.g., Zn), the geometric model is fairly accurate across the depth range, but data require a geometric correction. For higher masses, there is an increasing tendency to underestimate concentration. Using a "known" Cl concentration to model the depth, improved quantification is obtained for most elements at relatively shallow depths. Initial PIGE data have been obtained on a set of Butte inclusions for which PIXE data suggest low Cl concentrations of 0.2-0.8 wt% Cl, significantly below those assumed from microthermometry. Na peaks were clearly identified in a number of spectra, and quantification gave Na concentrations mainly between 0.1-0.6 wt%, broadly consistent with the PIXE data. These results indicate that Cl is unlikely to be the only anion present in these fluids, and that LA-ICP-MS results for ore metals are likely to be overestimated if using Na inferred from microthermometry.

P5B3
SYNCHROTRON X-RAY PROBE DEVELOPMENT

Leader /
Chris Ryan

Team Member /
Stacey Borg

Collaborators /
Joel Brugger, Gianluigi De Geronimo, Martin de Jonge, Paul Dunn, Barbara Etschmann, Jean-Louis Hazemann, Daryl Howard, Murray Jensen, Robin Kirkham, Tony Kuczewski, Weihua Liu, Gareth Moorhead, David Paterson, Peter Siddons, Denis Testemale

This project is developing new experimental equipment for probing samples of geological interest using the following synchrotron radiation applications at the Australian Synchrotron:

» The Maia detector - a high throughput, high-definition fluorescence detector for the XFM beamline.

» The mAESTRO system, a high pressure-temperature synchrotron spectroscopy cell for solution studies at the XAS beamline.

The new Maia 384 detector array was completed and commissioned on the XFM beamline, providing even higher image definition and sensitivity than the prototype. New methods and software were also developed to cope with data volume and provide real-time element images to users.

The mAESTRO system underwent a number of significant enhancements including extension of the maximum operating pressure to 600 bar, redesign of the heating system, upgrade of the heater power supply and controller system enabling full automatic computer control, and improved chemical sample cells.

P5B4
NEW SYNCHROTRON-BASED APPLICATIONS

Leader /
Stacey Borg

Team Member /
Chris Ryan

Collaborators /
Joel Brugger, James Cleverly, Barbara Etschmann, Steve Fraser, Jean-Louis Hazemann, Rob Hough, Weihua Liu, Denis Testemale

This year's focus has been on:

» The implementation of XANES imaging procedures for identification of chemical and redox states of specific elements spatially, on the micron scale, in geological samples.

» Continued probing of metal-ligand chemistry under conditions representative of ore-forming systems.

Successful synchrotron experiments included:

» XANES mapping experiments on the XFM beamline looking at As and Fe redox state and chemical speciation.

» The first non-commissioning mAESTRO experiments on the Australian Synchrotron XAS beamline.

» Follow-up investigation of Ni(II) in aqueous brines at 600 bar and up to 500 ºC.

» A study of reactivity and speciation of Mo(VI) oxides in chloride brines at 600 bar and up to 500 ºC.

» An examination of Zn speciation in NaBr brines at temperatures up to 150 ºC, at the ANBF, Tsukuba, Japan.

» Completion of data analysis of the data from the CoCl/CoBr study, and publication in *GCA*.

P5C2
IMPROVED IMAGE PROCESSING ALGORITHMS FOR LA-ICP-MS

Leader /
Anya Reading

Team Members /
Leonid Danyushevsky, Marcel Guillong, Sebastien Meffre

The aims are to:

» Improve the existing algorithms employed in processing image maps acquired by laser ablation.

» Develop new approaches to image generation.

During 2010, modelling of the laser ablation data collection process was undertaken, aiming to better understand the LA-ICP-MS imaging of small mineral inclusions, with a view to enable quantification of images in the future. It was demonstrated that when inclusions are the same size or smaller than the laser beam size, dramatically different images may result, depending on how the beam tracks over the inclusion.

A time-series analysis technique was applied to substantially remove memory effects at the interface of mineral grains with markedly different concentrations of one or more chemical elements. The technique was successfully demonstrated for silver located around the margin of pyrite grains, allowing the mineral associations to be more easily determined from the corrected image.

P5C3
MODELLING OF CRYSTALLISATION AND MELTING PROCESSES

Leader /
Leonid Danyushevsky

Student /
Kirill Bychkov

Collaborator /
Pavel Plechov

The aims are to:

» Develop model-independent algorithms for tracking the behaviour of trace elements during magma generation and evolution processes.

» Modelling of post-entrapment modifications in melt inclusions in minerals.

» Simulation of processes of mantle and crustal melting, and melt crystallisation.

» Develop a range of general petrological tools. These algorithms are continuously implemented in the future versions of the 'Petrolog' software package.

Petrolog v.3.1 was released during the year (http://petrolog.web.ru/), which contained enhanced algorithms for modelling melt crystallisation accompanied by H_2O degassing during magma ascent to the surface, and improvements to algorithms for modelling post-entrapment modifications to melt inclusions in olivine phenocrysts.

Outlook /

- » Development of sample preparation and handling techniques for LA-ICP-MS to improve precision and accuracy of the analysis.
- » Improving accuracy of fluid inclusion analysis by LA-ICP-MS, through quantification of depth-dependent elemental fractionation.
- » Developing new protocols for the in-situ analysis of Mo isotope compositions in molybdenite.
- » Correlation of electric field mapping and in-situ gold growth on sulfide minerals using the laser mapping and scanning electrochemical microscope.
- » Integration of PIXE, non-Rutherford backscattering spectrometry and IL analysis on quartz-hosted fluid inclusions within the new CSIRO nuclear microprobe chamber.
- » Implementation of XANES data cube analysis within GeoPIXE software.
- » Technique development for computer-corrected and enhanced images.
- » Release of Petrolog v.3.2, which contains a range of general petrological tools.

GRADUATE RESEARCH & TRAINING

Students enrolled in the UTAS Higher Degree by Research (HDR) Program make a major contribution to the research activities of the Centre of Excellence. Ninety per cent of HDR projects are integrated into the Centre's five research programs and about two-thirds of the projects involve collaborations with industry. HDR students have access to all of the Centre's equipment and facilities and are encouraged to take advantage of the wide range of expertise and experience offered by academic staff.

There were 54 students enrolled in the program during 2010, which included seven new PhD students – Jeff Steadman, USA; Daniel Gregory, Selina Wu and Marc Rinne, Canada; plus Matthew Cracknell, Sarah Gilbert and Brendan McGee from Australia. Fifteen PhD students and one MSc student had theses under examination, nine of whom graduated: Ralf Schaa, Paul Cromie, Jacqueline Blackwell, Adam Bath, Wojciech Zukowski, Ana Liza Cuison, Heidi Pass, Susan Belford, and Tim Ireland.

Ten PhD students suspended their candidature for part or all of the year, two chose to study part-time, and another two withdrew. This reduced the effective PhD workforce to around 45, which was lowered further to 35 by the larger-than-usual number of thesis submissions and graduations.

The 2010 HDR cohort included 37 international students representing 18 nationalities, fourteen of whom were at least partly funded by Centre of Excellence scholarships. CODES' success in attracting HDR students from overseas is underpinned by its international reputation as a research training centre, and ability to invest ARC Centre funds in scholarships. In addition, the program is generously supported by UTAS in the form of international student tuition fee waivers. It is also worth noting that three of the seven new students were Australian, the first for several years to be recruited nationally.

Many of CODES' HDR students are members of the UTAS Student Chapter of the Society of Economic Geologists. Jeff Steadman and Pedro Fonseca took over as co-presidents of the Chapter in 2010 and, together with the new committee, continued on the path of their predecessors by organising a wide range of events, both for professional development and recreation. A highlight of the year was a 10-day field excursion to Thailand and Laos in February, which included visits to five mines and a variety of interesting geological sites. Other events included a 2-day short course on fracture controlled hydrothermal ore systems, presented by Dr Stephen Cox; a lecture on the geology of Iran, by Professor Mohammad Hashem Emami; and a field trip to several Tasmanian mines, including Mt Lyell, Henty, Rosebery, Hellyer, Savage River and Beaconsfield.

The recreational program included a diverse mix of activities that ensured a high level of participation. Events included ice hockey, quiz nights, movie nights, wine and cheese tasting, barbecues and holiday parties.

Mathieu Ageneau and Fiona Best were both successful in gaining SEG Research Grants that will help fund their PhD research, and Heidi Berkenbosch acquired an SEG Graduate Student Fellowship Award.

Masters of Economic Geology Program /

It was another excellent year for the Masters of Economic Geology Program, which continued to go from strength to strength. For the first time, the number of students topped the 50 mark, a figure that represents over 60% of enrolments on the national program - a collaborative initiative between UWA, JCU and UTAS, known as the Minerals Geoscience Masters (MGM).

Four students completed the requirements of the degree during the year. You Jin Lee graduated in August after completing his research thesis entitled; *The Geological Setting and Mineralisation Characteristics of the Bong Mieu Mine, Central Vietnam*. You Jin was supervised by Associate Professor Khin Zaw. Colin Carter, David Freeman and Bruce Whittaker will graduate in 2011.

Three short courses were held. Jocelyn McPhie and Bruce Gemmell led the Volcanology and Mineralisation in Volcanic Terrains course in March, which included a noteworthy trip to the volcanically active White Island in the Bay of Plenty, New Zealand. The uninhabited island is notoriously difficult to reach, with all attempts to land by boat in previous years having failed. However, 'the class of 2010' were not daunted by previous failures and got around the problem by hiring two helicopters. Program manager, Tony Webster, led the other two courses: Brownfields Exploration and Ore Deposit Models and Exploration Strategies, held in June and November, respectively. All courses were full to capacity with the Volcanology course generating a significant waiting list. One of the most pleasing aspects of all three courses was the high percentage of Masters students in the enrolments; bearing in mind that the course is open to participants outside the program. In addition, the fact that many of the students were from partner universities bears testament to the program's growing status. As an example, in the Ore Deposit Models course most students were from outside UTAS.

Part of the program's success is that it is continually being updated and enhanced to meet the needs of the students. For instance, Brownfields Exploration incorporated a new format of intensive two and three-day workshops, including geochemical and 3D modelling. These were presented by two highly respected industry consultants, Scott Halley and Jun Cowan. In addition, Michael Roach from UTAS/CODES presented an introduction to geophysical techniques and GIS. Ore Deposit Models was presented by a broad cross-section of CODES researchers and included a presentation on uranium deposits by Roger Skirrow of Geoscience Australia. The course attracted many industry participants from as far afield as the Middle East, North America, South America, and Africa.

The program continued to be supported by the Minerals Council of Australia, through the Minerals Tertiary Education Council, which has played a significant role in its increasing success.

Twenty-two Honours students from UTAS, Melbourne University, ANU, Curtin and JCU completed the long-established Exploration Skills Mapping Course, led by Tony Webster and Andrew McNeill. The increasing popularity of this course with mainland universities resulted in it being full to capacity this year, with several people on the waiting list failing to gain a place. As a result, it has been decided to present the course twice in 2011.

The Honours year was administered by Garry Davidson, with Peter McGoldrick supervising the coursework aspects. Principal supervision was undertaken by Michael Roach (4), Anya Reading (2), Garry Davidson (2), Andrew McNeill, Tony Crawford, David Cooke, Anthony Harris, Emily Johnson, Stuart Bull, and Peter McGoldrick. Additional co-supervision was provided by Jocelyn McPhie, Sharon Allen, Jeff Foster, David Selley and Mike Baker, plus Mark Duffett from Mineral Resources Tasmania. Components of the internal MTEC and VIEPS Honours courses were taught by Tony Webster, Andrew McNeill, Garry Davidson, Leonid Danyushevsky, Jeff Foster, David Cooke, Bruce Gemmell, Rob Scott, Anya Reading, Michael Roach and Peter McGoldrick.

Honours Program /

Honours' enrolments had risen decisively the previous year, and this high level was maintained in 2010 with a total of 15 students, which is around the current capacity for the program. This figure includes two students that graduated mid-year, and three that were sourced from outside institutions - University of Newcastle, University of Adelaide, and the University of Canterbury, New Zealand.
Projects were spread across the disciplines in the following categories: economic geology (4), geothermal geophysics, resource geophysics (3), sedimentology and sedimentological geophysics (3), archaeological geophysics, volcanology, structure and geochronology, and igneous petrology. Six projects were based in Tasmania and one in New Zealand, with the remainder spread throughout Australia. Projects were sponsored by Mineral Resources Tasmania, Granite Power, Anglo American, Emmerson Resources, Pleiades Resources, MMG, Jabiru Metals, ASEG, and Highlake Resources.

OUTREACH

The Centre has developed a comprehensive strategy to bring a greater awareness of the earth sciences to the broader community. Key components of this strategy include a commitment to communicate across the full spectrum of demographic groups, and to include a mix of activities aimed at teachers and career advisors in the program.

Activities started with children as young as three and four years old. Sharon Allen visited the local Lady Gowrie Child Centre in June, where she introduced a large group of pre-schoolers to the wonders of volcanoes – demonstrating a 'pretend' eruption using vinegar and baking powder. Earlier in the year, CODES introduced the 'Gemnasium', which is a large bed of brightly polished rocks from around the world. This new feature is popular with all age groups, but is a particular favourite with the very young. Children love to fossick through the myriad of coloured stones searching for the most exotic looking 'gem'. The stones are also mounted on display boards and used in a variety of educational tools that teach the children about geology while they are also having fun. This feature has also proven popular with local community groups, such as the local Taroona Cubs, who were one of a number of ad hoc visitors during the year.

Primary schools, high schools and colleges were once again a major focus of the program in 2010, with over ten visits to CODES spread throughout the year. These visits were mostly supervised by Michael Roach, who provided entertaining and educational presentations on seismology, with a high level of audience participation. Other visits were hosted by Ross Large, Andrew McNeill and Karin Orth. CODES' staff also visited a number of these educational institutions. As an example, Rob Scott has committed to a series of visits to a local primary school to introduce students to the wonders of rocks and fossils.

The Centre continued its ongoing participation in the Science Experience initiative by hosting a workshop for Year-11 students early in the year. The program aims to inspire students to continue their science studies, and is supported by the Science Schools Foundation, Rotary and the Australian Science Teachers Association.

Twenty-one teachers and career advisors from secondary schools in Tasmania, Victoria and NSW visited the Centre in January as part of the annual UTAS Career Advisor Symposium. The visit was hosted by Bruce Gemmell and Michael Roach and included a presentation, a full tour of the facilities and a number of scientific demonstrations.

Support continued for the Teacher Earth Science Education Program (TESEP). This national program operates under the auspices of the Australian Science Teachers, and provides a series of professional development workshops aimed at upper primary / lower secondary school teachers. A further three workshops were held at the UTAS Hub during the year, which mixed interactive classroom and laboratory sessions with off-site field activities at local sites of geological interest.

For the older age groups, further lectures were held as part of the University of the Third Age (U3A) program, which seeks to improve the quality of life of mature-age people through a range of low-cost academic courses. Another initiative aimed at this demographic was a series of presentations to the School for Seniors. This group falls under the umbrella of the local Adult Education program, but operates in a less formal way than U3A. The main aims of the group are to mix companionship, fun and learning through a variety of educational and social events. In keeping with the format, Andrew McNeill delivered talks that covered an insight into the world of geology, interspersed with amusing anecdotes from his much-travelled career.

INDUSTRY LINKS & RESEARCH COLLABORATIONS

Objective /

» To be a research focus for the national and international minerals industry.

» Strategically collaborate with other top-level national and international research groups in the field of ore deposits, mineral exploration technologies and mineral processing.

CODES is recognised as a world leader in industry-linked, collaborative ore deposit research. Strong relationships have been developed with a range of industry partners and researchers who invest in, support and contribute to research projects. Fostering and growing these national and international collaborations will continue to be a key strategic focus, which will strengthen CODES' position as a premier centre for ore deposit research.

Industry Links and Synergies /

CODES has strong, enduring and mutually beneficial links with a large group of the major Australian and international mining companies. These links have been critical for funding CODES' research and for technology transfer to the mining and mineral exploration community.

In 2010, MMG joined the group of CODES' industry partners, which now comprises ten Australian and international mining companies: Anglo American, AngloGold Ashanti, Barrick Gold, BHP Billiton, MMG, Newcrest Mining, Newmont Mining, Rio Tinto, St Barbara Mines, and Teck.

Each of the partner companies provides support of $20,000 to $80,000 in cash per year to the research budget of the Centre. Senior representatives of these companies sit on the Science Planning Panel, along with other government and university researchers. This panel meets annually to discuss the results of CODES' research and the potential directions for new research.

CODES' industry partners benefit from sponsorship by having:

» Association with, and first call on, a world-class research team in ore deposit science.

» Membership of the CODES' Science Planning Panel.

» Access to scholarships for staff undertaking Masters degree courses.

» Fee reductions on regular short courses and special in-house courses.

» Branding exposure at national and international conferences and exhibitions.

Role of AMIRA International /

AMIRA plays a vital role in facilitating the funding of collaborative research involving university research groups and the minerals industry. AMIRA has agreed to fund a series of research projects within the Centre, which will run over a period of three to four years.

In 2010, AMIRA funded these major projects for CODES:

P765A Geochemical and geological halos in green rocks and lithocaps – The explorer's toolbox for porphyry and epithermal districts.

P843A (GeM^{III} project) Geometallurgical mapping and mine modelling.

P962 Ni-PGE potential of mafic and ultramafic – a combined melt inclusion and numerical modelling approach.

P1022 The rapid approximate inversion of TEM data.

P1041 Application of new technologies to gold deposits.

Research Collaborations and International Visitors Program /

In 2010, CODES further cemented its reputation for cultivating research collaborations with other Australian and international research organisations. During the year, collaborative research was conducted with 60 international and 19 national organisations.

Collaborative research between international and Australian-based partners is also being facilitated by joint research appointments. The table below details each of the collaborating institutions with the joint researchers and their funding source. These researchers are based at collaborating partner institutions and incorporate research visits to CODES throughout the term of their research projects.

Funding will continue to be used to support the International Visitors Program, which attracts high-profile researchers to CODES. In 2010, the following major international research collaborators were supported to visit CODES for more than three months each:

» PhD student Hossein Kouhestani from Tarbiat Modares University, Iran, visited Khin Zaw for six months, starting in July, to collaborate on epithermal deposits in Iran.

» Tim Lyons, from the University of California Riverside, visited Peter McGoldrick from March to June to collaborate on northern Australian Proterozoic Basin REDOX history.

» Thomas Pettke, from the University of Bern, visited Vadim Kamenetsky to collaborate on seafloor alteration of basaltic glass and fluid inclusions.

» PhD student Francisco Jose Testa from Universidad del Sur, Argentina, visited David Cooke for just over three months, starting in October, to collaborate on the Bi-Au-Cu San Francisco de los Andes breccia pipe deposit, San Juan Province, Argentina.

» PhD student, Lejun Zhang, from Hefei University, China, visited David Cooke for one year, starting in March, to collaborate on alteration and mineralisation of the Nihe-Fe deposit, Anhui province, China.

RESEARCHERS WHO WORK JOINTLY IN CODES AND THE COLLABORATING ORGANISATIONS

INSTITUTION	COE ARC GRANT	NODE MATCHING FUNDS	INDUSTRY / AMIRA FUNDS	UNIVERSITY / CSIRO FUNDS
University of Queensland (incl. Julius Kruttschnitt Mineral Research Centre & WH Bryan Centre)	Steve Walters (20%), Simon Michaux, Dee Bradshaw (12%), Alan Bye (11%), Italo Onederra (12%), Angus McFarlane (24%)	Angus McFarlane (20%), Steve Walters (11%)	Angus McFarlane (6%), Khoi Ke Nguyen, Luke Keeney, Italo Onederra (23%), Dee Bradshaw (14%), Steve Walters (50%), Louisa Groves, Alan Bye (11%)	Angus McFarlane (50%)
University of Melbourne	Bence Paul	Roland Maas		Janet Hergt
Australian National University	Angela Halfpenny			Stephen Cox
CSIRO Exploration and Mining	Jamie Laird (50%), Stacey Borg (50%)	Jamie Laird (50%), Stacey Borg (50%)		Chris Ryan, Weihua Liu

TECHNOLOGY TRANSFER

Objectives /

» Involve end-users (exploration and mining companies) in research planning, research evaluation and research adoption.

» Promote technology transfer so that innovative research outcomes are accessible to end-users.

» Comply with the national principles of intellectual property management for publicly funded research.

Technology Transfer Activities /

CODES undertakes strategic and applied research into the formation, location, discovery and recovery of ore deposits, and the development of innovative technologies to support these research endeavours. These initiatives create knowledge, processes, methods and solutions for the minerals industry and ore deposit researchers – locally, nationally and internationally.

Research results and technical developments in the applied research programs are transferred to end-users via regular research meetings, research reports, monographs, books, digital presentations and software packages, where appropriate. In 2010, 197 research reports were presented to industry clients, and meetings were held to present and discuss progress and adoption of research results.

Publications Targeted at End-Users /

CODES also delivers knowledge and applications to end-users and the wider scientific community through a selection of special publications that represent the culmination of major research efforts by the Centre's staff.

» Volcanic textures: a guide to the interpretation of textures in volcanic rocks (1993). Authors: J McPhie, M Doyle and R Allen (93 copies sold in 2010).

» New developments in Broken Hill-type deposits (1996). CODES Special Publication 1. Editors: J Pongratz and G Davidson (4 copies sold in 2010).

» Basins, fluids and Zn-Pb ores – CODES Special Publication 2 (1999). Editors: O Holm, J Pongratz and P McGoldrick (6 copies sold in 2010).

» Volcanic environments and massive sulphide deposits (2000). Editors: JB Gemmell and J Pongratz (7 copies sold in 2010).

» The geology and origin of Australia's mineral deposits (2000). Authors: M Solomon and D Groves (8 copies sold in 2010).

» Giant ore deposits: characteristics, genesis and exploration (2002). CODES Special Publication 4. Editors: D Cooke and J Pongratz (19 copies sold in 2010).

» 24ct Au workshop (2004). CODES Special Publication 5. Editors: D Cooke, C Deyell and J Pongratz (9 copies sold in 2010).

» Altered volcanic rocks: a guide to description and interpretation (2005). Authors: C Gifkins, W Herrmann and R Large (70 copies sold in 2010).

» The geology of the Broken Hill Pb-Zn-Ag deposit, NSW, Australia (2006). Author: A Webster (11 copies sold in 2010).

» Ore Geology Reviews – Special Issue (April 2007): mineral deposits of South China. Editors: Khin Zaw, S Peters, N Cook, Z Hou (5 copies sold in 2010).

Commercial Products and Processes /

Geometallurgical research in Program 4, in collaboration with JKMRC at the University of Queensland, has the potential to deliver a number of commercial outcomes for industry. Due to the commercial-in-confidence nature of this research, details of the specific outcomes cannot be released at this time.

Short Courses, Workshops and Conferences for End-Users /

Short courses and workshops continued to play a key role in the Centre's technology transfer activities. Throughout the year, a total of 27 courses were held at various locations around the world including Chile, China, Indonesia, Italy, Myanmar, New Zealand, Peru, Philippines and the USA.

Total attendance by industry geologists, academic researchers and postgraduate students was 811, with 20 presenters from the CODES' UTAS Hub, plus a number of students, involved in delivering the lectures.

2010 SHORT COURSES/WORKSHOPS/CONFERENCES LED BY CODES

TITLE	PRESENTERS*	NO.**	LOCATION	DATE
Ore Deposit Models of SE Asia	**Khin Zaw**	46	Yangon, Myanmar	2 Jan
Short Wavelength Infra-Red Techniques Workshop	**Zhaoshan Chang**	5	CODES, UTAS	18 Feb
Volcanology and Mineralisation in Volcanic Terranes, CODES Masters Short Course	**Jocelyn McPhie**	22	New Zealand and western Tasmania	7-21 Mar
Epithermal Gold Deposits: Characteristics, Processes, Products and Interpretation	Noel White	12	Newcrest Mining., Brisbane	7 Apr
Porphyry Deposit Geology: Their Igneous and Hydrothermal Alteration Geology	**Anthony Harris**	12	Newcrest Mining, Brisbane	8 Apr
Volcanoes and Their Products	**Jocelyn McPhie**	18	G-Resources, Martabe, Indonesia	26 Apr - 3 May
Workshop for Freeport Mining Company	**David Cooke, Zhaoshan Chang , Huayong Chen, Clara Wilkinson**	25	Manila, Philippines	17-18 May
VIEPS Ore Deposit Models	**Peter McGoldrick**	10	University of Melbourne	17-21 May
SEG-SGA-CUG Workshop Ore Deposit Models and Exploration	Steve Scott, **Zhaoshan Chang, Huayong Chen, David Cooke**, Craig Hart, David Leach, Chusi Li, Noel White, Kaihui Yang	262	Wuhan, China	24-29 May
Geometallurgical Mapping and Mine Modelling	**Jeff Foster**, Mansour Edraki, **Anita Parbhakar-Fox**, Italo Onederra, Simon Michaux, Hector Parra, Toni Kojovic, Steve Walters, Dee Bradshaw, Mitesh Chauhan, Kevin Pietersen, Laura Kuhar, Angus McFarlane, Byron Benvie, Gotam Das, **Ron Berry, Julie Hunt**, Khoi Nguyen	70	Brisbane	3-4 Jun
Short Wavelength Infra-Red Techniques Workshop	**Zhaoshan Chang**	7	CODES, UTAS	4 Jun
P765A – South American Workshop	**David Cooke, Bruce Gemmell, Zhaoshan Chang, Jamie Wilkinson**	32	Lima, Peru	16 Jun
P765A – South American Workshop	**David Cooke, Bruce Gemmell, Zhaoshan Chang, Jamie Wilkinson**	34	Santiago, Chile	21 Jun
Porphyry Ore Deposit Exploration: New and Existing Models	**Anthony Harris**, Dean Collett	13	Newcrest Mining, Brisbane	30 Jun
An Introduction to Ni Deposits	**Jeff Foster, Alexey Lygin**	15	Rosebery, Tasmania	10 Aug
P1022 Rapid Inversion of EM	Peter Fullagar, **Jeff Foster**	5	Sydney	10 Aug
Overview of the Zambian Copperbelt	**Stuart Bull**	38	MMG head office, Melbourne	28 Aug
Structure, Permeability and Fluid Flow in Fracture-controlled Hydrothermal Ore Systems	Stephen Cox	20	CODES, UTAS	21-22 Sep
P765A – North American Workshop	**David Cooke**, Jeff Hedenquist, **Huayong Chen**	19	Denver, USA	29 Sep
Metallogeny of Porphyry Cu-Au Deposits	Richard Tosdal, **David Cooke, Anthony Harris**, Paddy Waters, David Braxton, Andy Wurst	40	SEG Meeting, Keystone, Colorado, USA	6 Oct
Palaeozoic Porphyry Au-Cu Mineralisation in the Cadia Valley: System Scale and Zonal Arrangement: Newcrest Mining	**David Cooke**, John Holliday, **Anthony Harris, Mike Baker, Janina Micko**	18	Newcrest Mining, Cadia Valley Operations	20 Oct
Exploring the Lithocap and Greenrock Environment	**David Cooke, Mike Baker**	7	Newcrest Mining, Cadia Valley Operations	21 Oct
Fluids in the Earth	**Leonid Danyushevsky**	15	Università di Napoli Federico II, Italy	25-29 Oct
Ore Deposit Models and Exploration Strategies, CODES Masters Short Course	**David Cooke, Bruce Gemmell, Anthony Harris, Zhaoshan Chang, Huayong Chen**	37	CODES, UTAS	1-12 Nov
Field-based Structure Techniques for Exploration	**Steve Micklethwaite**	8 & 6	Gosowong, Halmahera, Indonesia	25 Nov & 5 Dec
Describing Altered Rocks	**Anthony Harris**	15	Newcrest Mining., Cracow Mine	14 Dec

* CODES' UTAS HUB PRESENTERS IN BOLD
** NUMBER OF ATTENDEES

PERFORMANCE INDICATORS

PERFORMANCE MEASURE	TARGET	2010
RESEARCH FINDINGS		
Publications in international journals	50pa	40
% of publications in A/A* journals	70	68
Reports to industry collaborators	80pa	197
Special issues and/or research monographs	1 per 2 years	0
Invitations to give keynote conference presentations	10pa	16
Papers at national/international meetings	70pa	103
INVESTIGATORS		
Average % of CIs research in Centre	70%	80%
Average % of PIs research in Centre	15%	20%
Percentage of team-based projects	80%	87%
Percentage of Australian cross-institutional projects	30%	40%
RESEARCH TRAINING AND PROFESSIONAL EDUCATION		
Percentage of RHD students attracted from interstate	40%	19%
Percentage of RHD students attracted from overseas	40%	69%
Honours students in Centre programs	10	15
RHD students in Centre programs	45	59 PhD, 3 MSc
Percentage of students in projects linked with industry	50%	75%
Professional short courses/workshops for industry	5pa	27
INTERNATIONAL, NATIONAL AND REGIONAL LINKS AND NETWORKS		
Centre national or international conferences/workshops	1 per 2 years	None
Registrants at Centre's conferences/workshops	100pa	811
International and national visitors per year	50pa	51
Collaborative projects with other global centres/groups	10pa	15
External collaborators using Centre's equipment	10pa	15

PERFORMANCE MEASURE	TARGET	2010
END-USER LINKS		
Frequency of meetings with industry representatives	15pa	22
End-user representatives to Science Planning Panel and Advisory Board	20% / 50%	40% / 42%
Frequency of meetings with AMIRA Research Coordinator	10pa	15
Number of industry visitors to Centre	80pa	102
ORGANISATIONAL SUPPORT		
Annual cash contributions from UTAS	$1,800,000	$2,107,854
Annual cash support from other collaborating universities & CSIRO	$205,000	$242,500
Annual cash support from industry	$2,000,000	$3,416,640
Number of new organisations recruited to or involved in the Centre	1pa	none
GOVERNANCE		
Joint post-doctoral appointments between collaborating institutions/organisations	5	7 (1 ANU, 1 UMelb, 2 CSIRO, 3 JKMRC)
Balance and experience of Advisory Board members		Excellent balance
Annual review of strategic and business plans		Yes
Effectiveness of Centre Research Committee		High
Effectiveness of Science Planning Panel		High
Public profile of Centre	High	High
NATIONAL BENEFIT		
Centre research has input into a major mineral discovery	1 per 5 years	None
Employment of Centre's postgraduates by minerals industry	>65%	85%

FINANCES

ARC Contract and Governance /

CODES became the Australian Research Council (ARC) Centre of Excellence (CoE) in Ore Deposits on 1 July, 2005. It was formerly an ARC Special Research Centre. The CoE contract with the Australian Government covers five years' funding from 2005 to 2010. At the mid-term review in November 2008, the ARC awarded an extension of funding for the period 2010 to 2013.

The Centre's financial affairs are conducted within the established procedures, controls and delegations of the University of Tasmania (UTAS) and the CoE's node universities and institutions. CODES has a policy of assigning budget responsibility to Node and Program Leaders, which is overseen by the Finance Manager and the Director.

To ensure the ARC's CoE requirements are met, an inter-institutional agreement was established by the UTAS Research Office, formally binding all participating institutions to the ARC CoE agreement, including funding allocations from the CoE to its nodes and agreed matching contributions made by those nodes.

The tables and figures presented in the following pages demonstrate the CoE is meeting the income and expenditure requirements of the current agreement.

2010 Income /

Total CODES income was $9.5 million (see Table 1). This was derived principally from industry (36%), the ARC (33%) and UTAS (22%) (see Figure 1). The main income streams over time are compared in Figure 2, demonstrating that ARC funding continues to be exceeded by other funding at a ratio of approximately 2:1 (the original CoE agreement with the ARC was 1:1). Therefore, non-ARC funding has consistently exceeded expectations since the start of the CoE, with industry funding showing the strongest growth.

The CoE collaborator/contributor cash income agreement

The CoE funding agreement with the ARC requires that approximately $3 million per annum ARC funding be matched, dollar for dollar, with agreed core funding from collaborators/contributors (N.B. annual ARC funding was reduced from $3 million pa to $2.7 million pa for the extension period, 1.7.2010 to 31.12.2013). This combined cash income is used to fund core research projects at the Centre. All agreed cash funding from the collaborators/contributors (except that of UQ and ANU nodes and some of the Industry Partners) was up to date at the end of 2010 (see explanation in the 'CoE node income' and 'industry income' sections on page 73 regarding this deficit). It should be noted that, in total, CODES has received $18.5 million more to-date towards CoE projects than was specified in the original agreement. This is mainly due to:

- Annual indexation of the ARC CoE Grant
- Significantly increased industry and AMIRA International funding
- Income from book sales, short courses and laboratory analyses
- Pre-existing funding from UTAS, ARC and AMIRA, which has extended into the CoE period.

All collaborator/contributor funding is paid to CODES annually, in cash, with the exception of funding from the CoE nodes, which is treated differently, as detailed under the heading 'CoE node income'.

In addition to the abovementioned cash income, the CoE receives a considerable amount of in-kind support from its collaborators/contributors, with UTAS providing the most substantial portion.

The following is a summary of the main income streams to the CoE in 2010:

- **ARC income:** The only ARC income received in 2010 was the CoE ARC Grant ($3 million). Total ARC funding decreased by $300k due to the following factors:
  - The ARC CoE Grant has been reduced by approximately 20% during the extension period
  - A previous Discovery Grant finished in 2010
  - There were no LIEF Grant funds awarded to CODES in 2010.
- **CoE node income:** The CoE's Australian nodes comprise the University of Queensland (UQ), University of Melbourne (U Melb), Australian National University (ANU) and CSIRO Exploration and Mining (CSIRO E&M). The CoE agreement requires that CODES transfers an agreed annual portion of its ARC CoE Grant income to each of the above nodes, to be expended at the node institutions. In return, the nodes agree to match this income with an agreed value of their own funds each year. Although these matching funds are counted as income to the CoE (Table 1), they are actually held and expended at the node institutions. Expenditure of both portions of node funding is reported annually to CODES. The UMelb node has received all of their agreed 2010 ARC income from CODES and contributed their matching funds to the Centre. In the case of the UQ, ANU and CSIRO E&M nodes, not all of these reciprocal transactions were able to take place for the July to December period because the CoE Extension Agreement had not been finalised. It is anticipated that the Agreement will be finalised shortly and these transactions will be included in the 2011 accounts.
- **State Government income:** The agreed three-year funding from the State Government of Tasmania ceased at the end of 2007.
- **Industry income:** Total industry funding in 2010 was $3.4 million, of which the largest contribution (43%) was from AMIRA International for CoE core and non-core research projects.

Industry funding decreased by 23% ($1 million) in 2010. This was mainly due to the following factors:

- Completion of a large AMIRA project in mid 2010
- Reduced funding to an extended AMIRA project
- A temporary $160,000 shortfall in Industry Partner income for the second half of the year, due to late finalisation of the CoE Extension Agreement – this will be rectified in 2011
- Industry income payments for a two-year period were made in 2009. This anomaly had the double effect of making last year's figure artificially high ($200k higher) and this year's income abnormally low
- $255k of funds from the AMIRA GeM[III] Project were transferred to UQ and will be counted as income to UQ (see Notes to Financial Statements)
- $118k income from UQ's CRC ORE could not be listed as income to CODES because it had already been counted as income to the CRC.

As demonstrated by the abovementioned points, there are a number of mitigating factors for this year's decrease in industry funding. However, over the life of the Centre, this funding remains well above the CoE Agreement target of $700k to $1.5 million per year.

- **Host institution support:** UTAS increased its core cash funding by 4% to $2.1 million, continuing an upward trend. This funding relates primarily to research salaries, PhD scholarships, equipment purchases and income earned by the Centre from research output. UTAS also provided over $1.8 million in in-kind support in 2010.

2011 Income Estimates /

Despite Australia escaping the worst effects of the global financial crisis, there is no doubt that it had a negative impact on income from industry in 2010. Although the outlook for the minerals industry is now more positive, a conservative view has been taken on industry funding for 2011 because companies are still taking a cautious approach to investment in research.

Although industry funding may decrease in 2011, and ARC funding will decrease due to a 20% funding reduction for the CoE extension period, all other income streams are expected to remain stable.

TABLE 1
CASH INCOME FINANCIAL STATEMENT 2005–2010

	(half year) 2005	2006	2007	2008	2009	2010
ARC - Centre of Excellence Grant						
CoE agreed core funding* – 2005 grant indexation (not received until 2006)	0	31,500	0	0	0	0
CoE agreed core funding* – ARC grant	1,500,000	3,121,198	3,184,402	3,248,088	3,313,864	3,097,230
	1,500,000	**3,152,698**	**3,184,402**	**3,248,088**	**3,313,864**	**3,097,230**
CoE nodes matching funds (agreed matching funds held at node institutions)						
CoE agreed core funding*	0	295,000	255,000	250,000	237,500	242,500
Additional funding (pre-existing or new)	0	0	0	0	0	0
	0	**295,000**	**255,000**	**250,000**	**237,500**	**242,500**
Other ARC grants						
CoE agreed core funding*	0	0	0	0	0	0
Additional funding (pre-existing or new)	328,791	397,325	394,338	471,524	403,889	0
	328,791	**397,325**	**394,338**	**471,524**	**403,889**	**0**
Other Commonwealth Government						
CoE agreed core funding*	0	0	0	0	0	0
Additional funding (pre-existing or new)	7,184	19,649	24,666	62,680	2,046	87,856
	7,184	**19,649**	**24,666**	**62,680**	**2,046**	**87,856**
State Government						
CoE agreed core funding*	200,000	200,000	200,000	0	0	0
Additional funding (pre-existing or new)	68,000	852	4,000	8,000	2,500	2,396
	268,000	**200,852**	**204,000**	**8,000**	**2,500**	**2,396**
Local Government						
CoE agreed core funding*	0	0	0	0	0	0
Additional funding (pre-existing or new)	0	0	0	0	0	0
	0	**0**	**0**	**0**	**0**	**0**
Industry/private						
CoE agreed core funding*	868,646	1,582,507	1,825,010	2,158,677	2,182,472	1,298,919
Additional funding (pre-existing or new)	444,803	909,552	938,913	1,487,935	2,268,323	2,117,721
	1,313,448	**2,492,059**	**2,763,923**	**3,646,611**	**4,450,795**	**3,416,640**
Contracts/consultancies/revenue raising						
CoE agreed core funding*	0	0	0	0	0	0
Additional funding (pre-existing or new)	143,787	286,675	306,743	368,160	383,012	411,097
	143,787	**286,675**	**306,743**	**368,160**	**383,012**	**411,097**
University of Tasmania - host institution support						
CoE agreed core funding*	343,744	1,334,728	1,147,471	1,128,759	1,430,393	2,107,854
Additional funding (pre-existing or new)	383,623	678,064	566,682	468,267	589,489	0
	727,367	**2,012,792**	**1,714,152**	**1,597,026**	**2,019,881**	**2,107,854**
Other income sources/interest						
CoE agreed core funding*	0	0	0	0	0	0
Additional funding (pre-existing or new)	4,348	60,006	53,000	131,585	25,147	84,795
	4,348	**60,006**	**53,000**	**131,585**	**25,147**	**84,795**
Total annual income	**4,292,926**	**8,917,056**	**8,900,226**	**9,783,674**	**10,838,635**	**9,450,368**
Grand total of all income to date						**52,182,885**

* CORE FUNDING LISTED IN THE COE AGREEMENT AND MATCHED TO THE ARC FUNDS

FIGURE 1
TOTAL CASH INCOME 2010

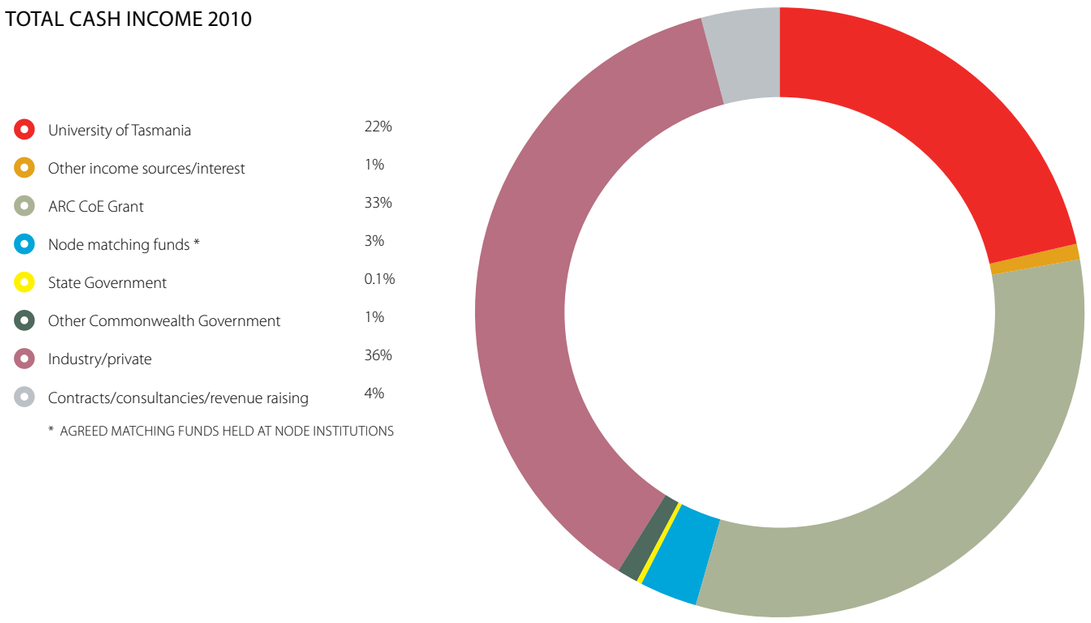
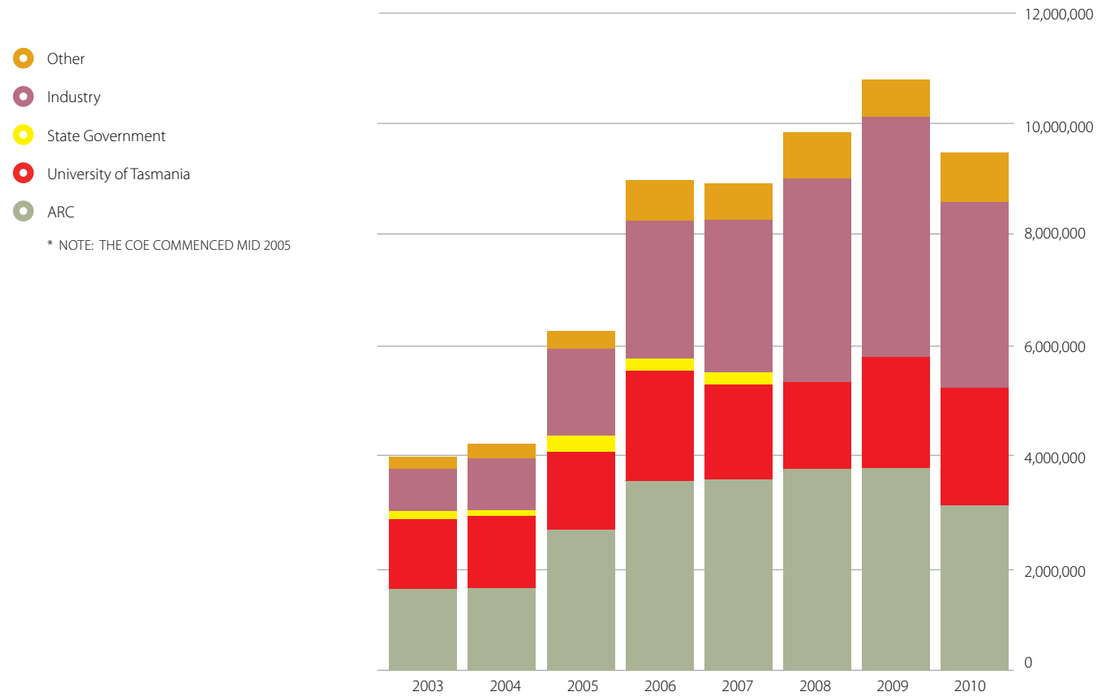


FIGURE 2
COMPARISON OF CODES' MAIN INCOME STREAMS 2003 – 2010



2010 Expenditure of ARC CoE Grant /

Summaries are provided in Table 2 and Figure 3 to show how CODES and its nodes have expended the ARC CoE Grant funds to date. As in past years, the major areas of expenditure in 2010 were salaries, research and field travel, student scholarships and laboratory analyses. However, most expenditure was lower than previous years due to decreased ARC funding.

The 2010 combined ARC CoE income and carry-forward of $3 million was offset by expenditure of $2.6 million, leaving a carry-forward surplus of $372k. However, it should be noted that the Centre currently owes $465k of 2010 funds to two of its nodes (UQ and CSIRO E&M). This amount was not able to be paid in 2010 due to late finalisation of the CoE Extension Agreement between UTAS and its nodes. If this had been paid in the year that it was due, the 2010 carry-forward balance would have been a deficit of $93k.

2011 Expenditure Estimates /

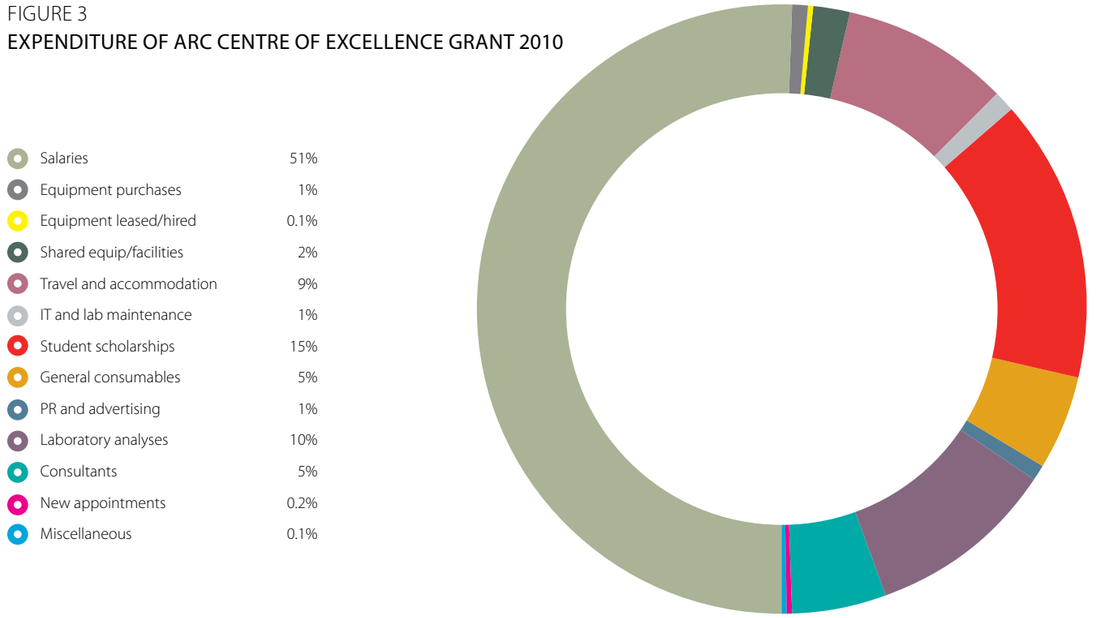
All expenditure in 2011 is expected to be lower than 2010 due to the reduction in ARC CoE Grant funding.

TABLE 2
EXPENDITURE OF ARC CENTRE OF EXCELLENCE GRANT 2005–2010 (CODES PLUS ITS NODES)

	(half year) 2005	2006	2007	2008	2009	2010
Income						
Balance brought forward from previous year	0	954,886	1,345,188	711,979	55,741	(145,268)
Miscellaneous income (refund of expenses)	0	8,497	29,589	43,155	0	18,704
ARC income	1,500,000	3,152,698	3,184,402	3,248,088	3,313,864	3,097,230
	1,500,000	**4,116,081**	**4,559,179**	**4,003,222**	**3,369,605**	**2,970,667**
Expenditure						
Salaries	(348,511)	(1,237,351)	(1,833,309)	(2,335,312)	(1,705,835)	(1,332,826)
Equipment purchases	(890)	(83,645)	(305,991)	(70,624)	(85,292)	(35,392)
Equipment leased/hired	(362)	(22,635)	(6,894)	0	0	(500)
Shared equipment/facilities	(1,119)	(21,900)	(46,750)	(58,188)	(109,407)	(54,919)
Travel and accommodation (research)	(52,363)	(354,349)	(314,206)	(282,161)	(364,065)	(221,763)
IT and lab maintenance	(1,866)	(91,292)	(208,688)	(145,441)	(82,620)	(16,334)
Student scholarships	(31,856)	(297,768)	(349,671)	(346,311)	(384,141)	(401,617)
General consumables/maintenance	(67,517)	(244,347)	(217,941)	(246,561)	(199,512)	(127,799)
Public relations and advertising	(9,289)	(105,160)	(119,364)	(53,466)	(66,299)	(36,158)
Laboratory analyses	(29,900)	(212,256)	(307,733)	(288,411)	(369,447)	(247,363)
Consultants	0	(90,290)	(108,075)	(68,962)	(62,186)	(117,203)
Visiting academics *	(9,002)	(9,900)	(19,311)	(41,665)	(61,221)	0
New appointment expenses	0	0	(9,267)	(10,381)	(22,523)	(5,564)
Miscellaneous	7,561	0	0	0	(2,323)	(906)
	(545,114)	**(2,770,893)**	**(3,847,200)**	**(3,947,481)**	**(3,514,872)**	**(2,598,343)**
Balance remaining at end of year	**954,886**	**1,345,188**	**711,979**	**55,741**	**(145,268)**	**372,323**

* FROM 2010 ONWARDS, VISITING ACADEMIC EXPENDITURE IS NO LONGER ITEMISED SEPARATELY

FIGURE 3
EXPENDITURE OF ARC CENTRE OF EXCELLENCE GRANT 2010



Notes to, and Forming Part of, the Financial Statements for 2010 /

The financial pages of this Annual Report were prepared by Christine Higgins, CODES' Finance Manager. Data for the financial statements was extracted from the UTAS TechOne Financial System and CODES' financial databases. All Financial Statements shown here have been reviewed and audited by UTAS.

Income statement explanations

The income figures in Table 1 represent actual income recorded in the University's finance system or transferred internally from UTAS to CODES during 2010, with the following exceptions:

» The CoE node matching funds are listed as cash income in the income statement (Table 1), but are not actually received as cash by the Centre. These matching funds, contributed by the nodes, are held and expended at the node institutions and reported annually to the CoE. They are listed as cash income in Table 1 to demonstrate that the nodes are providing their agreed annual contribution to the CoE

» $255k of AMIRA GeM^{III} Project funds were deposited into a UTAS account, but were later transferred to UQ for a joint research project. These funds will be listed as AMIRA income to UQ, therefore they cannot also be listed as income to CODES

» $118k income from UQ's CRC ORE cannot be listed as income to CODES because it has already been listed as income to the CRC.

In Table 1, sub-categories labelled 'CoE agreed core funding' are used to isolate core funding from other general funds. This is in accordance with the ARC requirement that the Centre demonstrates that these agreed core funds have been received each year.

Because of the six-month delay to the establishment of CODES as a CoE, very few agreed cash payments between the CoE and its nodes/collaborators were contributed in 2005. As a result, the payments for this six-month delay period were made during 2006. This has artificially inflated 2006 income figures by approx $400,000 (i.e. node income +$50,000, UTAS +$200,000, Industry Partners +$130,000). Therefore, any comparison between 2006 and 2007 income figures needs to take this into account.

In 2008, there was a minor retrospective amendment made to the 2005 industry/private income figure, which has increased the 2005 income total by $20,000. This relates to $20,000 of CoE agreed 2005 income, which was paid in advance by Teck Cominco (now Teck Resources) in 2004. It has already been counted in the 2004 income statement of the SRC, but it is now listed again in the CoE's 2005 data (in the year that it was due) to clearly demonstrate to the ARC that Teck Cominco has met its CoE funding obligations within the five-year CoE agreement period.

Expenditure statement explanations

All expenditure categories are consistent with last year's reports, except for the following change:

» From 2010 onwards, 'visiting academic' expenditure is no longer itemised separately. This expenditure is now included in the appropriate other categories (e.g. travel, analyses, consumables etc).

The expenditure financial statement and pie chart (Table 2 and Figure 3) include the following:

» CODES' expenditure of ARC CoE Grant funds (administered by UTAS)

» The nodes' expenditure of ARC CoE Grant funds (administered by the node institutions and reported annually to UTAS).

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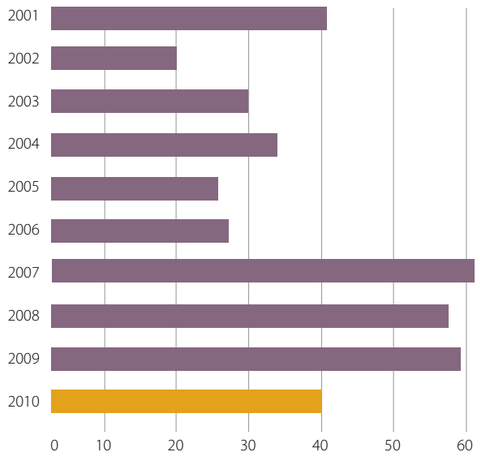

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APPENDICES

CODES Postgraduate Students 2010 /

STUDENT	SUPERVISOR(S)	PROJECT	SUPPORT
BACHELOR OF SCIENCE (HONOURS) (15)			
Emma Brown*	Johnson, Allen	Pumice vesicle of the 15.8ka Rotorua eruptive episode, New Zealand: implications for eruptive dynamics and conduit processes	CODES
Paul Donaldson*	Roach, Bull	Facies architecture and radar stratigraphy of the Seven Mile spit, Tasmania	SES, MRT
Josh Guilliamse*	McGoldrick	Early Mesoproterozoic microbial vent communities from the Century deposit, NW Queensland	MMG
Ben Hey*	Roach, Reading	A geophysical reconnaissance of archaeological sites on Maria Island Tasmania	Tas Gov/DPIPWE,SES
Nicholas Jervis-Bardy*	Reading, Roach	Geophysical investigation of Eneabba geothermal prospect, WA	Granite Power Ltd, TGMS
Hamish Johns*	G. Davidson, Large	Characterisation of the Northern Star uranium mineralisation, Northern Territory, with special emphasis on IOCG relationships	Emmerson Resources Ltd, TGMS
Kyen Knight*	Reading, Roach	Geophysical characterisation of Rosebery ore body and host environment	MMG
Ting Kor^	Harris, Cooke, Chang	Hydrothermal breccias at the Coalstoun porphyry Cu-Au-Mo deposit, SE Queensland	Newcrest
Daniel Macklin*	G. Davidson, McNeill	Alteration at the Teutonic Bore (VHMS) deposit Western Australia	Jabiru Metals Limited, TGMS
Brendan Sargent*	Roach, Reading	Geophysical characterisation of the Roaring 41 South prospect, Balfour	Pleiades Resource
Markus Staubmann^	Crawford, McNeill	The petrogenesis and economic potential of the Southern Cavenagh Range intrusion (west Musgraves), Western Australia	Anglo American
Tim Stubley*	Selley, McNeill	The structure and stratigraphy of the Ironbound Group, Southwest Tasmania, Australia	CODES
Michael Tomlin*	Roach, Duffett (MRT)	Optimised gravity survey design	TGMS, ASEG
Katherine Webb*	Cooke, Crawford	The Boorhaman intrusive complex, Victoria - geology, geochemisty, geochronology	CODES, Highlake Resources
Allison Whitfield^	Bull, G. Davidson	Sedimentology and detrital zircon geochronology of the Permo-Triassic transition in the northern Tasman Peninsula, Tasmania	TGMS, SES
MASTER OF ECONOMIC GEOLOGY (54)			
Paluku Batsotsi		coursework only	African Mining Consultants
Lynelle Beinke		coursework only	Heathgate Resources
Jeffrey Bigelow		coursework only	Newmont
John Brewster		coursework only	Newcrest Mining Limited (Cracow GM JV)
Mark Burdett		coursework only	Monash University
Adrian Byass		coursework only	Ironbark Gold Ltd
Cesar Calderon Tipiani	Cooke	Determining the geochemical halo around intermediate sulfurized epithermal system veins and its use as an exploration vector to neighboring (like) systems	Hochschild Mining PLC
Colin Carter		coursework only	Bluestone Tin (Renison Mine)
Corrie Chamberlain	Gemmell	Geology, geochemistry and genesis of the Kilkenny low sulfidation epithermal deposit, Cracow, Queensland	Newcrest Resources Inc
Mathieu Chatenet		coursework only	Argonaut Resources
Jo Condon	Gemmell	Mineralisation characterisation of the Doolgunna prospect: Implications for mining, milling and exploration	Sandfire Resources NL
Richard Cotton	Berry, Webster	The geology of the Ross Alluvial gold deposit and its implications for gold sourcing on the West Coast, South Island, New Zealand.	Solid Energy New Zealand Ltd
Monica Davis		coursework only	Palaris

STUDENT	SUPERVISOR(S)	PROJECT	SUPPORT
Martin De La Cueva Torres	Cooke	Characterisation of the mineralising fluids and mineralogical and geochemical zoning of the Pucuy and Sausa Au deposits and their relation with the Chimpo deposit, Orcopampa-Arequipa, Peru	Compania de Minas Buenaventura
Glen Diemar	Kamenetsky, Ehrig (BHP Billiton), McPhie	Geochronology of hydrothermal REE minerals and their relationships with economic mineralisation at the Olympic Dam breccia complex, South Australia	BHP Billiton Olympic Dam
Mike Everitt	Webster	An aspect of the grade distribution of the Savage River magnetite deposit	Grange Resources Ltd
George Eyong Ndoh Tabi		coursework only	unknown
David Freeman		coursework only	AngloGold Ashanti Australia Limited
Phil Gilmore	Webster	An aspect of the geology of the Koonenberry Belt, NSW	Geological Survey of NSW
Zoe Hatzopoulos		coursework only	unknown
Margy Hawke	Gemmell	Geology of the DeGrussa prospect, WA: Implications for ore genesis and exploration	Sandfire Resources NL
Mark Hotson		coursework only	University of Tasmania
Alex Johnston		coursework only	Private Contracter
Brian Kay	Foster	Combined economic and geologic evaluation of eastern Australian gold projects - selection of acquisition targets	Northgate Australian Ventures
Martin Kent		coursework only	Rio Tinto
Chris Large		coursework only	Cam Bow
You Jin Lee	Zaw	Geological setting and mineralisation characteristics of the Bong Mieu mine, Central Vietnam.	Korea Resources Corporation
Yungu Lim	Zaw	Geological setting and mineralisation characteristics of Steung Nambrai-Elephant Au-base metal system, eastern Cambodia	Korea Resources Corporation
Neil Macalalad		coursework only	Anglo American Exploration Philippines Inc
Ador Makuei		coursework only	Geoscience Australia
Kane Maxwell	Webster	A review of the grade control drilling processes at Poitrel coal mine and their application in mine planning.	BMA
David Meade		coursework only	Bluestone Tin (Renison Mine)
Phillip Micale		coursework only	Beaconsfield Mine JV
Miguel Miranda Trinidad	Cooke, Chang	Thesis topic not yet known	Buenaventura
Noah Muzuva		coursework only	Copper Mines of Tasmania
Olufolajimi Ogunleye		coursework only	unknown
Mathew O'Neill		coursework only	unknown
Katie Perrin		coursework only	Neptune Minerals Plc
José Polanco-Rodriguez		coursework only	Barrick
Anna Price		coursework only	unknown
Anthony Raimondo		coursework only	unknown
Scott Randall		coursework only	AngloGold Ashanti Beijing Rep Office
Steven Richardson	Gemmell	The Fossey Zone, Hellyer Mine	Bass Metals
Alan Riles		coursework only	Riles Integrated Resource Management Pty Ltd
Jonathan Robbeson		coursework only	Perilya Broken Hill Ltd

STUDENT	SUPERVISOR(S)	PROJECT	SUPPORT
Daud Silitonga		coursework only	PT.Nusa Halmahera Minerals (Newcrest Mining Group)
Linda Sprigg		coursework only	OZ Minerals
Leo Subang	Cooke	coursework only	Freeport McMoRan Exploration Corp
Edward Summerhayes		coursework only	Silver Lake Resources
Pearse Sweeney		coursework only	Moultrie Geology
Jason Triffit		coursework only	unknown
Bruce Whittaker		coursework only	OZ Minerals
Yong Zhang		coursework only	AngloGold Ashanti
Stanley Zutah		coursework only	Gold Fields

MASTER OF EXPLORATION GEOSCIENCE (1)

Terence Hoschke*	Large, Roach	Geophysical signatures of gold-copper porphyry systems	

MASTER OF SCIENCE (2)

Paul Ferguson	G. Davidson, Roach	Origins of large negative anomalies in oceanic crust, Macquarie Island	SEG
Siddarth Paleri (UMelb)	Hergt (UMelb), Paul (UMelb)	Spatial systematics of copper isotope fractionation in the Rainbow hydrothermal vent field, 36°14'N, Mid-Atlantic Ridge	UMelb

DOCTOR OF PHILOSOPHY (59)

Andrea Agangi*	Kamenetsky, McPhie, Allen	Magmatic and volcanic evolution of giant intraplate felsic igneous provinces: Gawler Range Volcanics and Hiltaba Suite, South Australia	TPRS co-fund, CoE, PIRSA
Mathieu Ageneau	Cooke, Gemmell, Danyushevsky	Geology of the Kapit ore zone and comparative geochemistry with Minifie and Lienetz ore zones, Ladolam gold deposit, Lihir Island, Papua New Guinea	Lihir Gold Ltd, Newcrest, SEG, UTAS
Mohd Basril Iswadi Bin Basori	Khin Zaw, Large	Geology of volcanic hosted massive sulfide (VHMS) deposits in Central Belt, Peninsular Malaysia	Malaysian Govt, Ore deposits of SE Asia Project
Adam Bath^	Kamenetsky, Crawford, Cooke	The geochemistry of melt inclusions and mineral phases from the Mount Polley and Lorraine (Canada) alkalic Cu-Au porphyry deposits: implications for the formation of ore deposits	BCGS, SEG, CoE Top-up, APA, Alkalic project, UBC, MDRU
Susan Belford^	G. Davidson, McPhie, Large	Genetic and chemical characterisation of the Archaean Jaguar VHMS deposit	APA-I, SEG, Jabiru Metals Ltd
Heidi Berkenbosch	Gemmell, McNeill, de Ronde (GNS)	Geochemistry of hydrothermal mineral chimneys from Brothers volcano, Kermadec arc	CoE, GNS Science, UTAS
Fiona Best	Crawford, Foster	The petrogenesis of the Dido Tonalite, northern Queensland	CoE, Anglo American, UTAS, SEG
Jacqueline Blackwell^	Cooke, McPhie	Characteristics and origins of breccias in an alkalic epithermal gold deposit: Ladolam, Lihir Island, Papua New Guinea	CoE, Alkalic project, SEG/ Newmont, SEG Canada, TPRS co-fund, LGL Gold
Natalee Bonnici	Walters, Berry	The mineralogical and textural characteristics of Cu-Au deposits related to mineral processing attributes	GeM[III] project, TGRS
Victoria Braniff	Webster, Berry	The structure and deformational history of the Savage River magnetite orebodies, NW Tasmania	Grange Resources Ltd
Kirill Bychkov	Danyushevsky, McNeill	Numerical modelling of sulfide precipitation from mafic magmas with implications for the formation of layered intrusions	CoE, UTAS
Mitesh Chauhan (JKMRC)	Bradshaw (UQ)	Application of small scale flotation testing	GeM[III] project
Lindsey Clark	Gemmell, Cooke, Micklethwaite	The geology and genesis of the Kencana epithermal Au-Ag deposit, Gosowong goldfield, Halmahera Island, Indonesia	Newcrest, SEG
Gisela Cobenas Benites	Danyushevsky, Falloon	Metal and volatile contents of primitive subduction-related magmas (Hunter Ridge, SW Pacific): assessing magmatic contributions to volcanic-hosted seafloor mineralisation	UTAS
Matthew Cracknell	Reading, Foster	Innovative data inference from spatial datasets in earth science	UTAS

STUDENT	SUPERVISOR(S)	PROJECT	SUPPORT
Mawson Croaker*	Selley, McGoldrick, Bull	Geology and genesis of the Nkana copper deposit, Zambia	AMIRA, TPRS
Paul Cromie^	Khin Zaw, Cooke, White	Geological setting, geochemistry and genesis of the Sepon mineral district, Laos PDR	Oxiana, SEG, CSIRO, APA
Ana Liza Cuison^	Cooke, Harris, Berry	Geology and genesis of the Ridgeway porphyry Au-Cu deposit, NSW	Newcrest, SEG
Quang Sang Dinh	Crawford, Berry	Geochronology and geological evolution of the northern margin of the Kontum massif, central Vietnam	Vietnamese Govt., CODES
Cathy Evans (JKMRC)*	Walters, Johnson (UQ), Manlapig (UQ), Kojovic (UQ)	The relationship between mineral characteristics or ores and the variation in their processing attributes	GeM[III] project
Nathan Fox	Cooke, Harris	Controls on alteration and mineralisation in the Cadia East Au-Cu porphyry copper deposit, NSW, Australia	Newcrest
Victor Hugo Galvan-Guiterrez	Cooke, Gemmell, McPhie	Palmarejo carbonate base-metals silver-gold epithermal deposit, Trogan project, Chihuahua, Mexico	IPRS, Couer d'Lane
Sarah Gilbert	Danyushevsky, Guillong, Large	Development of analytical methods and standard reference materials for determination of trace element concentrations and isotopic ratios in sulfur-rich minerals and silicate glasses	CoE, CODES
Sarah Gordee	McPhie, Allen	Characteristics of submarine volcanic facies in oceanic arc depocentres	TPRS co-fund, CoE
Daniel Gregory	Large, Bull	Pyrite black shales: a source of gold for orogenic gold deposits, St Ives district, W Kambalda WA	CoE, UTAS
JianXiang Guan	Danyushevsky, Crawford	Origin of associated magnetite and sulfide mineralisation in large gabbroic intrusions: A LA-ICP-MS study of minerals and melt inclusions from the Panzhihua and Taihe intrusions in Emeishan LIP and Duluth Complex	CoE, UTAS
Timothy Ireland^	Cooke, Berry	Geological framework of porphyry and epithermal mineralisation in the Collahuasi district, Tarapacá, Chile	APA, AMIRA (P765), SEG (McKinstry Fund), Newmont Mining Corporation
Nicholas Jansen	Gemmell, Chang	Geology and geochemistry of the Ixhuatan lithocap, and its relationships to porphyry and epithermal mineralisation	AMIRA P765a, Kinross
Benjamin Jones	Large, Crawford	Tectonic setting and magmatic evolution of the Antapaccay porphyry copper-gold and skarn deposit, Peru	BHP, APA Scholarship
Martin Jutzeler	McPhie, Allen	Behaviour of submerged eruption plumes using data from facies analysis of a variety of submarine pyroclastic successions	CoE, USGS, UTAS
Teera Kamvong	Khin Zaw, Meffre	Geology and genesis of porphyry-skarn Cu-Au deposits at the northern Loei fold belt, Northeast Thailand and Laos	IPRS, ARC Linkage, CoE, SEG, Pan Australian
Luke Keeney (JKMRC)^	Walters, Morrison (UQ)	Integrated geometallurgical modelling of the Cadia East deposit	GeM[III] project
Roisin Kyne	Berry, Gemmell	Structural controls on mineralisation, including sulfide mineralogy, at the CSA mine, Cobar NSW	UTAS, Cobar Management Ltd
Chun Kit Lai	Crawford, Meffre, Khin Zaw	Tectonics and metallogenesis of ophiolites and volcaanics in southwestern Yunnan, China	CoE, Ore Deposits of SE Asia project, UTAS
George Leigh (JKMRC)^	Gay (UQ), Morrison (UQ)	Multi-resolution image analysis for process mineralogy	GeM[III] project
Alexey Lygin	Foster, Crawford	The geology, geochemistry and genesis of the Avebury Ni deposit, Tasmania	CoE, MMG
Wallace Mackay*	Selley, Bull	Sedimentology and structure of the Curdimurka Subgroup, Willouran Range, South Australia	APA-I, AMIRA
Rodney Maier*	McGoldrick, Large	Pyrite trace element halos to northern Australian SEDEX deposits	Anglo American
Takayuki Manaka	Khin Zaw, Meffre	Geology and mineralisation characteristics of the Phuoc Son goldfields, central Vietnam	CoE, UTAS, Ore Deposits of SE Asia project, SEG, Olympus Pacific Minerals
Brendan McGee	McNeill, Gemmell	The geology and mineralisation of the Tala Hamza Pb-Zn deposit, Algeria	Terramin Australia, UTAS
Claire McMahon	G. Davidson	Controls on the major and trace elements content of pyrite in hydrothermal alteration envelopes	ARC
Janina Micko (MDRU)^	Tosdal (MDRU), Dipple (MDRU)	The geology and genesis of the Central Zone alkali copper-gold porphyry deposit, Galore Creek district, northwestern British Columbia, Canada	Alkalic project
Robert Josephus Moye Jr	Cooke, Scott	Genesis and chemical and kinematic evolution of the late Proterozoic Ridgeway gold deposit in the Carolina terrane of the central South Carolina piedmont, USA	CoE, Kennecott Minerals, Kennecott Exploration Inc, SEG, TPRS Scholarship
Anita Parbhakar-Fox	Walters, Edraki (UQ)	Texture-based approaches to predictive geo-environmental modelling	SEG, GeM[III] Project

STUDENT	SUPERVISOR(S)	PROJECT	SUPPORT
Hector Ivan Parra Galvez (BRC)	Onederra (BRC)	Quantifying the impact of blast induced fragment conditioning on leaching performance	GeM[II] project
Heidi Pass^	Cooke, G.Davidson, Chang	Breccia-hosted chemical and mineralogical zonation patterns of the Northeast zone. Mt Polley Cu-Au-Ag alkalic porphyry deposit, British Columbia, Canada	Imperial Metals, TPRS co-fund, SEG
Pedro Pereira da Fonseca	McPhie, McNeill	Strato-tectonic setting of massive sulfide deposits: Mount Read Volcanics (western Tasmania) and the Iberian Pyrite Belt (Portugal)	Portuguese Govt, CoE
Kevin Pieterson (JKMRC)	Walters (UQ), Berry, Bradshaw (UQ)	Geological and geometallurgical texture discrimination	GeM[II] Project
Marc Rinne	Cooke, Harris, Micko	Characteristics and relationships of the contrasting Wafi-Golpu Cu-Au porphyry- epithermal system, Papua New Guinea	Newcrest, Harmony Gold, Morobe Mining Joint Venture, UTAS
Abhisit Salam	Khin Zaw, Meffre, McPhie	Geology and genesis of the Chatree deposits, Phetchabun Province, central Thailand	Kingsgate Consolidated Ltd, IPRS, SEG, ARC Linkage, CoE
Ralf Schaa^	Fullagar, Roach, Reading	Rapid approximate 3D inversion of transient electromagnetic data	APA-I, CODES
Blackwell Singoyi	G.Davidson, Khin Zaw, Large	Controls on the geochemistry of magnetite in hydrothermal fluids	IPRS, CODES, TGMS, SEG
Jeffrey Steadman	Large, Bull, G.Davidson	The source of Au in banded iron formation (BIF)- hosted gold deposits	SEG, CSIRO
Bronto Sutopo	Gemmell, Cooke	The Martabe Au-Ag high-sulfidation epithermal mineralisation in the Tapanuli Selatan district, North Sumatra Province, Indonesia: implications for ore genesis and exploration	Newmont Mining Corporation
Sofia Tetroeva	Danyushevsky, Crawford	Petrology and geochemistry of adakites and related rocks from the Hunter Ridge, Southwest Pacific	UTAS, CODES
Olga Vasyukova*	Kamenetsky, G.Davidson, Danyushevsky	The origin of quartz and fluid inclusions in mineralised porphyries	CoE, IPRS
Adel Vatandoost Kohnehshahri*	Roach, Walters, Fullagar	Automated petrophysical characterisation of drill core as a link to mineral processing attributes	GeM[II] project
Selina Wu	McNeill, Gemmell, Large	Volcanic hosted massive sulfide deposits of the Que-Hellyer Volcanics, western Tasmania	Bass Metals
Wojciech Zukowski^	Cooke, Gemmell	Geology and mineralisation of the Endeavour 41 gold deposit, Cowal district, NSW, Australia	Barrick, SEG

* DEGREE COMPLETED, BUT NOT YET GRADUATED
^ GRADUATED

Research Collaborations with CODES 2010 /

INSTITUTION	RESEARCHER(S)	CODES' COLLABORATOR(S)	PROJECT
NATIONAL COLLABORATIONS (IN ADDITION TO CENTRE PARTNERS)			
Australian Museum, Sydney	Lin Sutherland	Khin Zaw	Ore deposits of SE Asia
Australian National University	Charlotte Allen, Ian Campbell	Anthony Harris	Exploring the porphyry environment
Australian National University	Hugh O'Neill	Leonid Danyushevsky	Mafic magmatism in modern submarine SW Pacific settings
Australian National University	Malcolm Sambridge	Anya Reading, Jeff Foster, Matt Cracknell	Data inference techniques
Australian National University	Marc Norman	Leonid Danyushevsky	New LA-Q-ICP-MS applications
Australian National University	Nicholas Rawlinson	Anya Reading	Ambient seismic energy techniques
Australian National University	Steve Eggins	Vadim Kamenetsky	Unmixing in magmas
Australian Synchrotron	David Paterson, Daryl Howard, Martin de Jonge	Chris Ryan	Synchrotron X-ray probe development
CSIRO, Perth	John Walshe, Rob Hough	Ross Large, Dan Gregory, Jeff Steadman, David Cooke	Relationship between gold and organic matter in orogenic gold deposits
CSIRO, Perth	John Walshe	Ross Large	Fluids that form high-salinity, volcanic-hosted massive sulfide
CSIRO	Murray Jensen, Robin Kirkham, Gareth Moorhead, Paul Dunn	Chris Ryan	Synchrotron X-ray probe development
CSIRO	James Cleverly, Steve Fraser, Rob Hough	Chris Ryan	New synchrotron-based applications
Geological Survey of New South Wales	Ian Percival	Anthony Harris	Exploring the porphyry environment
Geological Survey of Queensland	Ian Withnall	Tony Crawford, Mike Baker	Palaeoproterozoic magmatism and mineralisation
Geoscience Australia	David Huston, Terry Mernagh	Khin Zaw	VHMS deposits
Geoscience Australia	Terry Mernagh, Bill Papas	Sebastien Meffre	LA-Q-ICP-MS analysis development
James Cook University	Bob Henderson	Tony Crawford	Tasman Line tectonics and mineralisation potential
James Cook University	Thomas Blenkinsop	Steve Micklethwaite	Identifying hidden structure with faults, fractals and geomorphology
Macquarie University	Elena Belousova	Jocelyn McPhie, Vadim Kamenetsky	Setting of Olympic Dam
Mineral Resources Tasmania	Ralph Bottrill, Jafar Taheri	Tony Webster, Victoria Braniff, Ron Berry	Savage River magnetite deposit
Monash University	Massimo Raveggi	Leonid Danyushevsky	New LA-Q-ICP-MS applications
Monash University	Reid Keays	Tony Crawford	PGE in palaeoproterozoic mafic sills at Broken Hill
Primary Industries and Resources South Australia	Martin Fairclough	Jocelyn McPhie, Vadim Kamenetsky	Felsic magmas in volcanic arcs and intraplate volcanic provinces
University of Adelaide	Joel Brugger, Barbara Etschmann	Chris Ryan	Synchrotron X-ray probe development and new synchrotron-based applications
University of Melbourne	Brett Johnson, Jeff McCallum	Jamie Laird	Ion beam analysis development
University of Melbourne	Jon Woodhead	Leonid Danyushevsky	Mafic magmatism in modern submarine SW Pacific settings
University of Melbourne	Mark Kendrick	Vadim Kamenetsky	Unmixing in magmas
University of Melbourne	Roland Maas	Sebastien Meffre	New LA-Q-ICP-MS applications
University of Melbourne	Roland Maas	Tony Crawford, Jocelyn McPhie, Vadim Kamenetsky	Palaeoproterozoic magmatism and mineralisation, Olympic Dam
University of New South Wales	Ian Graham	Khin Zaw	Ore deposits of SE Asia
University of Sydney	Patrice Rey	Steve Micklethwaite	Subduction polarity switches
University of Queensland	Paulo Vasconcelos, Sue Golding	Khin Zaw	Ore deposits of SE Asia
University of Western Australia	Mark Barley	Khin Zaw	Ore deposits of SE Asia

INTERNATIONAL COLLABORATIONS (IN ADDITION TO CENTRE PARTNERS)

INSTITUTION	RESEARCHER(S)	CODES' COLLABORATOR(S)	PROJECT
AAAS GSA/USGS, USA	Larry Meinert	Zhaoshan Chang	Efficiency of ore-forming processes
American Museum of Natural History, USA	James Webster	Paul Davidson	Melt-melt immiscibility and the origin of magnetite-apatite deposits
Brookhaven National Laboratory, USA	Gianluigi De Geronimo, Tony Kuczewski, Jan Peter	Chris Ryan	Synchrotron X-ray probe development
Chiang Mai University, Thailand	Phisit Limtrakun, Sampan Singharajwarapan, Weerapan Srichan	Khin Zaw, Tony Crawford	Ore deposits of SE Asia
Chinese Academy of Geological Science, China	Zengqian Hou	Khin Zaw	VHMS deposits
Colorado School of Mines, USA	Thomas Monecke	Bruce Gemmell	Hydrothermal event recognition and targeting in volcano-sedimentary strata
Colorado State University, USA	Holly Stein	Khin Zaw	Ore deposits of SE Asia
Consultant	Joey Garcia	Zhaoshan Chang	Efficiency of ore-forming processes
Department of Mineral Resources, Thailand	Pol Chaodumrong	Khin Zaw	Ore deposits of SE Asia
Department of Mineral Resources, Thailand	Somboon Khositanont	Khin Zaw, Sebastien Meffre	Ore deposits of SE Asia
ETH Zurich, Switzerland	Jung Hun Seo, Markus Waelle	Marcel Guillong	New LA-Q-ICP-MS applications
Geological Survey of Canada	Wayne Goodfellow, Jan Peter	Bruce Gemmell	Hydrothermal event recognition and targeting in volcano-sedimentary strata
GFZ German Research Centre for Geosciences, Germany	Ilya Veksler	Vadim Kamenetsky	Unmixing in magmas
GFZ German Research Centre for Geosciences, Germany	Rainer Thomas	Paul Davidson	Melt-melt immiscibility and the origin of magnetite-apatite deposits
Ghent University, Belgium	Marlina Elburg	Vadim Kamenetsky	Unmixing in magmas
Hanoi University of Mining and Geology, Dept of Geology, Vietnam	Hai Thanh Tran	Khin Zaw	Genesis of volcanic-hosted copper-lead-zinc-silver-gold massive sulfide deposits
Hanoi University of Mining and Geology, Dept of Geology, Vietnam	Hai Thanh Tran	Khin Zaw, Jacqui Halpin	Ore deposits of SE Asia
Hefei University of Technology, China	Taofa Zhou, Yu Fan, Feng Yuan	David Cooke, Zhaoshan Chang, Huayong Chen	Polymetallic mineralisation and associated magmatic and volcanic activity in Cretaceous volcano-sedimentary basins of eastern China
IFM-GEOMAR, Germany	Armin Freundt	Sharon Allen, Jocelyn McPhie	Explosive degassing of submarine felsic magmas
IFREE JAMSTEC, Japan	Yoshihiko Tamura	Sharon Allen, Jocelyn McPhie	Explosive degassing of submarine felsic magmas
Imperial College London, UK	Andrew Berry	Anthony Harris	Exploring the porphyry environment
Imperial College London, UK	Andrew Berry	Leonid Danyushevsky	Mafic magmatism in modern submarine SW Pacific settings
Imperial College London, UK	Dominik Weiss	Jamie Wilkinson	Transition metal speciation and isotope systematics of source rocks for sediment- and volcanic-hosted ores
Imperial College London, UK	Jamie Wilkinson, Clara Wilkinson	David Cooke, Bruce Gemmell, Zhaoshan Chang	AMIRA P765A: Geochemical and geological halos in green rocks and lithocaps - The explorer's toolbox for porphyry and epithermal districts
Institut Neel and European Synchrotron Radiation Facility, France	Denis Testemale, Jean-Louis Hazemann	Chris Ryan	Synchrotron X-ray probe development and new synchrotron-based applications
Institute of Experimental Mineralogy, Russia	Eduard Konnikov	Leonid Danyushevsky	Ni-PGE potential of mafic and ultra mafic magmas – a combined melt inclusions and numerical modelling approach
Institute of Geological and Nuclear Sciences, New Zealand	Kevin Faure	Anthony Harris	Exploring the porphyry environment
Institute of Geological and Nuclear Sciences, New Zealand	Cornel de Ronde	Bruce Gemmell, Heidi Berkenbosch	Active base- and precious-metal-rich massive sulfide deposition
Institute of Geology and Geophysics, Chinese Academy of Sciences, China	Neng Jiang	Paul Davidson	Melt-melt immiscibility and the origin of magnetite-apatite deposits
Institute of Geology and Mineralogy, Russia	Sergei Smirnov	Vadim Kamenetsky	Unmixing in magmas
Institute of Geology, Chinese Academy of Geological Sciences, China	Zhiming Yang	Zhaoshan Chang	Efficiency of ore-forming processes
Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, Russia	Alexander Borisov	Leonid Danyushevsky	Ni-PGE potential of mafic and ultra mafic magmas – a combined melt inclusions and numerical modelling approach
Lakehead University, Canada	Peter Hollings	Jeff Steadman, Ross Large	Sediment- and volcanic-hosted gold
Lakehead University, Canada	Peter Hollings	David Cooke, Bruce Gemmell, Zhaoshan Chang	AMIRA P765A: Geochemical and geological halos in green rocks and lithocaps - The explorer's toolbox for porphyry and epithermal districts
Laurentian University, Canada	Steve Piercey	Bruce Gemmell	Hydrothermal event recognition and targeting in volcano-sedimentary strata
McGill University, Canada	Jeanne Paquette	Zhaoshan Chang	Efficiency of ore-forming processes
Moscow State University, Russia	Pavel Plechov	Leonid Danyushevsky	Modelling of crystallisation and melting processes
Muroran University, Japan	Yoshi Goto	Jocelyn McPhie	Submarine volcanism and the Iberian Pyrite Belt
National Laboratory of Energy and Geology, Portugal	Carlos Rosa	Jocelyn McPhie	Submarine volcanism and the Iberian Pyrite Belt
National Oceanography Centre, UK	Darryl Green	Janet Hergt	New stable isotope MS applications
Niigata University, Japan	Katsuki Kurokawa	Sharon Allen, Jocelyn McPhie	Explosive degassing of submarine felsic magmas
Queen's University, Canada	Dan Layton-Matthews	Bruce Gemmell	Hydrothermal event recognition and targeting in volcano-sedimentary strata
Russian Academy of Science, Russia	Valeriy Maslennikov	Ross Large	Sediment- and volcanic-hosted gold
Smithsonian Institution, USA	Richard Fiske	Sharon Allen, Jocelyn McPhie	Submarine explosive eruptions and degassing of felsic magmas
South Dakota School of Mines & Technology, USA	Colin Patterson	Jeff Steadman, Ross Large	Sediment- and volcanic-hosted gold
State Key Laboratory in Ore Deposits, China	Xieyan Song	Tony Crawford, Leonid Danyushevsky	Ni-PGE potential of mafic and ultra mafic magmas – a combined melt inclusions and numerical modelling approach
United States Geological Survey	Poul Emsbo	Peter McGoldrick	Global ocean chemistry, marine basins and mineralisation
Universidade Federal Minas Gerais, Brazil	Rosa Figueiredo e Silva, Steffen Hagemann	Garry Davidson	Cracking the sulfate isotopic composition problem in ancient hydrothermal systems: application of the Carbonate-Associated Sulfate (CAS) method
Universiti Kebangsaan Malaysia	Mohd Rozi Umor, Wan Fuad Wan Hassan	Khin Zaw	Ore deposits of SE Asia
Universiti Kebangsaan Malaysia	Wan Fuad Wan Hassan	Khin Zaw	Genesis of volcanic-hosted copper-lead-zinc-silver-gold massive sulfide deposits
University of Alberta, Canada	Robert Creaser	Anthony Harris	Exploring the porphyry environment
University of Bern, Switzerland	Thomas Pettke	Vadim Kamenetsky	Unmixing in magmas
University of Bern, Switzerland	Thomas Pettke	Marcel Guillong	New LA-Q-ICP-MS applications
University of British Columbia, Canada	Greg Dipple	Janina Micko	Exploring the porphyry environment
University of British Columbia, Canada	Jim Mortensen	Bruce Gemmell	Genesis of volcanic-hosted copper-lead-zinc-silver-gold massive sulfide deposits
University of British Columbia, Canada	Rich Friedman	Janet Hergt	New LA-Q-ICP-MS applications

INSTITUTION	RESEARCHER(S)	CODES' COLLABORATOR(S)	PROJECT
University of British Columbia, Canada	Richard Tosdal	Anthony Harris, Janina Micko, David Cooke	Exploring the porphyry environment
University of California Berkeley, USA	Rebecca Carey	Sharon Allen, Jocelyn McPhie	Explosive degassing of submarine felsic magmas
University of California Riverside, USA	Tim Lyons	Peter McGoldrick	Global ocean chemistry, marine basins and mineralisation
University of Central Missouri, Dept of Earth Science, USA	John Nold, Mark Dudley	Paul Davidson	Melt-melt immiscibility and the origin of magnetite-apatite deposits
University College of Science, Iran	Mirsaleh Mirmohammadi	Paul Davidson, Leonid Danyushevsky	Melt-melt immiscibility and the origin of magnetite-apatite deposits
University of Hannover, Germany	Roman Botcharnikov	Vadim Kamenetsky	Unmixing in magmas
University of Lisbon, Portugal	Jorge Relvas	Jocelyn McPhie	Submarine volcanism and the Iberian Pyrite Belt
University of Lisbon, Portugal	Miguel Gaspar	Zhaoshan Chang	Efficiency of ore-forming processes
University of Malaya	Teh Guan Hoe, Azman Ghandi	Khin Zaw	Genesis of volcanic-hosted copper-lead-zinc-silver-gold massive sulfide deposits
University of Malaya	Teh Guan Hoe	Khin Zaw	Ore deposits of SE Asia
University of Naples, Italy	Benedetto De Vivo	Leonid Danyushevsky	Mafic magmatism in modern submarine SW Pacific settings
University of Oregon, USA	Ilya Bindeman	Vadim Kamenetsky, Marcel Guillong	Unmixing in magmas
University of Oregon, USA	Kathy Cashman	Sharon Allen, Jocelyn McPhie	Explosive degassing of felsic magmas
University of Oregon, USA	Paul Wallace	Emily Johnson, Vadim Kamenetsky, Jocelyn McPhie	Volatiles in felsic magmas
University of Otago, New Zealand	David Craw	Ross Large, Helen Thomas	Sediment- and volcanic-hosted gold
University of Ottawa, Canada	Mark Hannington	Bruce Gemmell	Hydrothermal event recognition and targeting in volcano-sedimentary strata
University of Ottawa, Canada	Jeff Hedenquist	David Cooke, Bruce Gemmell, Zhaoshan Chang	AMIRA P765A: Geochemical and geological halos in green rocks and lithocaps - The explorer's toolbox for porphyry and epithermal districts
University of Pisa, Italy	Paolo Fuglinati, Paola Marianelli, Alessandro Sbrana	Vadim Kamenetsky	Unmixing in magmas
University of Science and Technology, China	Yuling Xie	Paul Davidson	Melt-melt immiscibility and the origin of magnetite-apatite deposits
University of the Witwatersrand, South Africa	Allan Wilson	Leonid Danyushevsky	Ni-PGE potential of mafic and ultra mafic magmas – a combined melt inclusions and numerical modelling approach
Vernadsky Institute, Russia	Alexey Ariskin	Leonid Danyushevsky	Ni-PGE potential of mafic and ultra mafic magmas – a combined melt inclusions and numerical modelling approach
Virginia Polytechnic, USA	Robert Bodnar	Leonid Danyushevsky	Mafic magmatism in modern submarine SW Pacific settings
Woods Hole Oceanographic Institution, USA	Chris German	Janet Hergt	New stable isotope MS applications

Visitors to CODES 2010 /

INDUSTRY VISITORS

Paul Agnew	Rio Tinto
Zdislav Apetsius	ALROSA
Emmanuel Baah-Danso	Newmont
Bradley Baker	BHP Billiton
Fabian Baker	Lydian International
Ed Baltis	Gold Fields
Paluku Batsotsi	African Minerals (Barbados)
Lynelle Beinke	Heathgate Resources
Steve Beresford	MMG
Gabriele Bressen	BHP Billiton
David Braxton	Anglo American
Matt Briggs	St Ives Gold Mining
Graeme Broadbent	Rio Tinto
Rex Brommecker	Barrick
David Burrows	Vale
Cameron Cairns	Pan Australian Resources
Keith Cameron-Smith	Bass Metals
Chris Campbell	Newmont Asia Pacific
Genesio Circosta	Issaramining
Dean Collett	Newcrest
Jun Cowan	Prestologic
John Cooke	Equinox Minerals
Paul Cromie	Tiger Realm Group
Matthew Crowe	BHP Billiton
Lynda Daley	Newmont Asia Pacific
Graeme Davis	Kinross Gold
Kim Denwer	Bass Metals
Cathy Dickins	St Barbara
Glen Diemar	BHP Billiton
Nick Direen	FROGTech
John Dow	Dowgold
John Dobe	Barrick
Kathy Ehrig	BHP Billiton
Doug Ellinger	OZ Minerals
David First	Freeport McMoRan
David Freeman	Minotaur Exploration
Fred Fryer	Agilent
Alan Goode	AMIRA International
Dave Gibson	Grange Resources
Scott Halley	Mineral Mapping
Eamon Hannon	Fortescue Metals Group
Ben Harper	Gold Fields
Zaidi Harun	Monument
Nick Hayward	Teck
Dedy Hendrawan	Rio Tinto
John Holliday	Newcrest Mining
Erin Holmes	Earth Data
Terry Hoschke	Newmont Asia Pacific
Neil Hughes	MMG
Bruce Hutchinson	Grange Resources
Teera Kamvong	Barrick Gold
Sung-Yong Kang	Korean Resources Corporation
Peter Langley	Kenelec
Chris Large	Cam Bow
Mark Lindsay	Newmont
Steve Loach	BHP Billiton

Angela Lorrigan	Bendigo Mining
Neil Macalalad	Anglo American
Grant MacDonald	Bass Metals
John MacDonald	BHP Billiton
Michael Macdonald	Rio Tinto
Glen Masterman	Kinross Gold
David Meade	Indochine
Cheryl Morton	African Explorer
Jonas Mota e Silva	Votorantim Metais
Tim Mueller	SIPA Resources
Ashley Norris	Resonetics
Matthew O'Neill	NSW coal company
James Patterson	MMG
Aubrey Paverd	Compania de Minas Buenaventura
Annette Pocock	AngloGold
Paul Polito	Anglo American
Mike Richards	Equinox Minerals
Alan Riles	Riles Consulting/AMC
Steven Richardson	Bass Metals
Nic Rosengren	BHP Billiton
Dean Rossell	Rio Tinto
David Royle	EMX Exploration

Travis Schwertfeger	Corvette Resources
Lee Sampson	Barrick Gold
Donna Sewell	AngloGold Ashanti
Robina Sharpe	MMG
Michael Shelley	Laurin Technic
Daud Silitonga	PT.Nusa Halmahera Minerals
Jim Sinclair	AngloGold Ashanti
Larry Stewart	MMG
Leonardo Subang	Freeport McMoRan
Naoki Sugiyama	Agilent
Bronto Sutopo	Newmont
John Thompson	Teck
Stephen Turner	Newmont Asia Pacific
Lisa Jane Vella	Teck Australia
David Wallace	MMG
Edward Ward	Exploration Geologist
Michael Whitbread	Newcrest Mining
Ian Willis	Anglo American
Peter Winterburn	Vale
Andy Wurst	Gold Fields
Yong Zhang	Longxin Minerals

NATIONAL ACADEMIC AND GOVERNMENT VISITORS

Richard Arculus	Australian National University
Stacey Borg	CSIRO
Tony Brown	Mineral Resources Tasmania
Cristiana Ciobanu	University of Adelaide
Nigel Cooke	University of Adelaide
Stephen Cox	Australian National University
Philip Gilmore	Geological Survey NSW
Andrea Giuliani	University of Melbourne

Dave Green	Mineral Resources Tasmania
Geoff Green	Mineral Resources Tasmania
Angela Halfpenny	Australian National University
Richard Hartner	University of Queensland
Paul Heithersay	Department of Primary Industries and Resources of South Australia
Janet Hergt	University of Melbourne
Jon Huntington	AuScope
Kate Kiseeva	CSIRO

Toni Kojovic	JKMRC
Laura Kuhar	CSIRO
Roland Maas	University of Melbourne
Terry Mernagh	Geoscience Australia
Simon Michaux	JKMRC
Bill Papas	Geoscience Australia
Bence Paul	University of Melbourne

Brad Pillans	Australian National University
Roger Skirrow	Geoscience Australia
John Walshe	CSIRO
Steve Walters	JKMRC
Jon Woodhead	University of Melbourne
Greg Yaxley	Australian National University

INTERNATIONAL ACADEMIC AND GOVERNMENT VISITORS

Alexey Ariskin	Vernadsky Institute, Russia
Therese Bejgarn	Luleå University of Technology, Sweden
Anthony Chappez	University of California Riverside, USA
Mike Coffin	UK Oceanography Centre, UK
Maxim Gavrilenko	Institute of Volcanology and Seismology, Russia
Hesham Harbi	King Abdulaziz University, Saudi Arabia
Jeff Hedenquist	University of Ottawa, Canada
Peter Hollings	Lakehead University, Canada
Eduard Konnikov	Institute of Experimental Mineralogy, Russia
Hossein Kouhestani	Tabiat Modares University, Iran
Tim Lyons	University of California Riverside, USA

Marcelo Marquez	University of Patagonia, Argentina
Thomas Pettke	University of Bern, Switzerland
Peter Sorjonen-Ward	Geological Survey of Finland
Francisco Testa	Universidad Nacional del Sur, Argentina
Hai Thanh Tran	Hanoi University of Mining and Geology , Vietnam
James White	University of Otago, New Zealand
Jamie Wilkinson	Imperial College London, UK
Clara Wilkinson	Natural History Museum, London, UK
Lejun Zhang	Hefei University of Technology, China
Zhiming Yang	Institute of Geology, Chinese Academy of Geological Sciences, China

Major Externally Funded Research Projects /*

AMIRA-ARC CENTRE OF EXCELLENCE PROJECTS 2010†

INVESTIGATOR(S)	PROJECT	INDUSTRY PARTNERS	PERIOD	COE-ARC FUNDING FOR 2010	AMIRA FUNDING FOR 2010	MISC FUNDING FOR 2010	ADDITIONAL AMIRA FUNDING FOR 2010
Foster, Walters, Edraki, Berry, Kojovic, Michaux, Onederra, Bradshaw, Robinson, Jeffrey	AMIRA P843A. GeM[III] Geometallurgical Mapping and Mine Modelling (extension)	Anglo American, AngloGold Ashanti, ALS, Barrick Gold, BHP Billiton, Boliden, Codelco, Datamine, Gold Fields Australia, ioGlobal, Metso, Minera San Cristobal, Newcrest Mining, OZ Minerals, Quantitative Geoscience, Rio Tinto, Teck, Vale Inco, Xstrata Copper	July 2009 - 2013	$500,000	$772,259	$1,346	$441,389 (UQ) $471,228 (Parker Centre) $118,050 (CRC Ore- UQ)
Cooke, Gemmell, Chang, Baker, Chen	AMIRA P765A. Geological and geochemical halos in green rocks and lithocaps: The explorer's toolbox for porphyry and epithermal districts	Anglo American, AngloGold Ashanti, Barrick Gold, Cia De Minas Buenaventura, Codelco, CVRD, Dundee Precious Metals, Equinox Resources, Freeport McMoran, Gold Fields, Kinross Gold, MMG, Newcrest Mining, Newmont Mining, Rio Tinto, St Barbara, Teck, Xstrata	2008 - 2011	$114,000	$676,000	$42,160	$33,200 (Lakehead University)
Large, Thomas, Bull, Meffre, Danyushevsky, Scott	AMIRA P1041. Application of new technologies to gold deposits	AngloGold Ashanti, Newcrest Mining, Newmont Mining, G-Resources, Issara Mining, Sipa Exploration	2010 - 2013	$45,000	$118,200	$0	$0
Foster, Schaa, Fullagar (Fullagar Geophysics)	AMIRA P1022. The applied rapid approximate inversion of TEM data	AngloGold Ashanti, Gold Fields Australia, Rio Tinto, Mira Geoscience	2010 - 2013	$50,000	$36,000	$0	$0
Danyushevsky, McNeill, Feig, Ariskin (Vernadsky), Konnikov (IEM)	AMIRA P962. Ni-PGE potential of mafic and ultramafic magmas - a combined melt inclusion and numerical modelling approach	Anglo American, BHP Billiton, Votorantim Metals	2007 - 2010	$43,673	$28,993	$0	$7,500 (Ariskin) $2,500 (Konnikov)

ARC DISCOVERY GRANTS 2010^

INVESTIGATOR(S)	PROJECT	PERIOD	ARC FUNDING FOR 2010	MISC FUNDING FOR 2010
Allen	Discovery Grant: Submarine explosive eruptions of silicic magma: constraints on products and processes from modern sea-floor examples, ancient successions and experiments	2004 - 2012	**	$0

INDUSTRY AND OTHER EXTERNALLY FUNDED RESEARCH GRANTS 2010

INVESTIGATOR(S)	PROJECT	FUNDING BODY	PERIOD	FUNDING FOR 2010	MISC FUNDING FOR 2010
Harris, Cooke, Micko, Tosdal (UBC)	Exploring the porphyry environment	Newcrest Mining Limited	July 2009 - 2013	$352,679	$0
Khin Zaw, Meffre	Ore Deposits of SE Asia	Indochine Resources Ltd, Newmont Asia Pacific, Barrick Gold, OZ Minerals, Pan Australian Resources, Kingsgate Consolidated Ltd/Issara Ltd, Southern Gold Ltd, MMG, Monument Mining	2008 - 2010	$340,000	$0
Micklethwaite, Gemmell, Cooke, Blenkinsop (JCU)	Enabling blind exploration- identifying hidden structure with faults, fractals and geomorphology	Newcrest Mining Limited	2010 - 2012	$207,115	$0
Gemmell, Micklethwaite	Deposit to district-scale study of the Gosowong Goldfield	Newcrest Mining Limited	2007 - 2010	$148,309	$1,960
Foster, Hutchinson	Tenor variation in the Tweefontein Sector of the Platreef, South Africa	Anglo American Exploration Luxembourg SARL	2008 - 2010	$112,310	$216
McPhie, V Kamenetsky, Chambefort	Mafic igneous facies at Olympic Dam	BHP Billiton	2008 - June 2010	‡	$27
McPhie, V Kamenetsky	Setting, age and architecture of the Olympic Dam Au-Cu-U deposit, South Australia	BHP Billiton	July 2010 - 2012	$107,316	$0
Cooke, Gemmell, Chang, Zukowski	Geological and geochemical vectors to epithermal silver-gold mineralisation, Ares mine, Araquepa, Peru	Compania Minera Area S.A.C.	2009 - 2010	$95,014	$0
Berry, Kyne (student)	Structural controls on mineralisation, including sulfide mineralogy, at the CSA mine, Cobar NSW	Cobar Management Pty Ltd	2009 - 2013	$90,000	$0
Large, Gregory (student), Steadman (student)	Gold and organic matter; why are they commonly related?	CSIRO	2010	$70,000	$0
McNeill, Wu (student)	Volcanic hosted massive sulphide deposits of the Que-Hellyer Volcanics, western Tasmania	Bass Metals	2010 - 2013	$56,500	$0
Webster, Braniff (student)	The structure & deformational history of the Savage River Magnetite orebodies	Grange Resources (formerly Australian Bulk Minerals)	2008 - 2012	$55,000	$0
Scott	Carlin Au pilot study	Evolving Gold Corporation	2010	$25,138	$0
Crawford, Best (student)	The petrogenesis of the Dido Tonalite, northern Queensland	Anglo American	2009 - 2010	$19,182	$545
McNeill, McGee (student)	The Geology and Mineralisation of the Tala Hamza Pb-Zn deposit, Algeria	Terramin Australia Ltd	2010 - 2013	$16,000	$0
G Davidson, McNeill, Macklin (student)	Alteration at the Teutonic Bore (VHMS) deposit Western Australia	Jabiru Metals Limited	2010	$13,636	$0
Cooke, Gemmell, Ageneau (student)	Geology of the Kapit ore zone and comparative geochemistry with Minifie and Lienetz ore zones, Ladolam gold deposit, Lihir Island, Papua New Guinea	Newcrest Mining Limited (formerly Lihir Gold Ltd)	2009 - 2011	$10,000	$0
Cooke, Crawford, Webb (student)	The Boorhaman intrusive complex, Victoria - geology, geochemisty, geochronology	Highlake Resources	2010	$10,000	$0
G Davidson	Geochemical controls on gold, Sunrise Dam	James Cook University	2010 - 2011	$9,000	$0
G Davidson, Large, Johns (student)	Characterisation of the Northern Star uranium mineralisation, Northern Territory, with special emphasis on IOCG relationships	Emmerson Resources Limited	2010	$7,000	$0
McGoldrick, Guilliamse (student)	Early Mesoproterozoic microbial vent communities from the Century deposit, NW Queensland	MMG	2010	$6,000	$0
Reading, Roach, Jervis-Bardy (student)	Geophysical investigation of Eneabba geothermal prospect, WA	Granite Power Limited	2010	$5,000	$4,384
Reading, Roach, Knight (student)	Geophysical Characterisation of Rosebery Ore Body and Host Environment	MMG	2010	$4,500	$0
Roach, Tomlin (student)	Optimised Gravity Survey Design	Australian Society of Exploration Geophysicists	2010	$4,210	$0
Ageneau (student)	Hugh E. McKinstry Fund	Society of Economic Geologists Foundation	2010	$4,000	$0
Best (student)	Hugh E. McKinstry Fund	Society of Economic Geologists Foundation	2010	$3,430	$0
Clark (student)	SEG 2010 Conference Grant	Society of Economic Geologists Foundation	2010	$2,600	$0

* PROJECTS WITH GREATER THAN $2,000 EXTERNAL (NON-COE-ARC) FUNDING PER YEAR
† ARC FUNDING FOR THESE PROJECTS COMES FROM THE COE-ARC GRANT
^ ARC FUNDING FOR THESE PROJECTS COMES DIRECTLY FROM THE ARC DISCOVERY OR LINKAGE PROGRAMS
** ALL PROJECT FUNDING RECEIVED, PROJECT STILL ACTIVE
‡ FULL PROJECT FUNDING RECEIVED IN ONE YEAR

ACTIVITY PLAN 2011

PROJECT	LEADER(S)	ACTIVITY PLAN
PROGRAM 1		
P1A1	Tony Crawford	Complete PGE study of the Broken Hill mafic sills with Reid Keays of Monash University. In collaboration with Barney Stevens of GS-NSW, complete the study of facing in the Broken Hill mafic sills, aimed at elucidating the 'way up' of the ore bodies.
P1A2	Leonid Danyushevsky	Complete major and trace element bulk rock and main rock-forming mineral analysis of representative rocks from various volcanic series in the Hunter Ridge, SW Pacific - collected during the voyage of RV *Southern Surveyor* in 2009. Submit a publication on the oxidations state of backarc and arc magmas. Conduct a detailed study of compositions of clinopyroxene phenocrysts, and their melt inclusions, from a range of plinian and strombolian eruptions of Vesuvius.
P1A3	Peter McGoldrick	Produce second paper with the University of California Riverside group, using mid-Proterozoic ferruginous oceans to explain why some SEDEX systems make supergiant stratiform Zn-anomalous pyrite deposits, whereas others make supergiant high-grade Zn-Pb deposits. Produce a paper describing Century organisms, and present at a suitable conference. Conduct a provenance study of the Rocky Cape Group using paleo-redox and zircon.
P1A4	Khin Zaw, Sebastien Meffre	Complete proposal for an extension to the Ore Deposits of SE Asia Project, and present at the CODES' Science Planning Meeting in April. Negotiate with current and new sponsor companies. Hold an implementation meeting for the new follow-on project in June.
P1A5	Tony Crawford, Jeff Foster	Project discontinued.
P1A6	Tony Crawford	Publication in *Australian Journal of Earth Sciences* of key findings of the N Tasman Line – Greenvale project. Completion of Fiona Best's PhD, and preparation of paper describing the geology, geochronology and petrogenesis of the Dido Batholith in N Queensland.
P1B1	Jocelyn McPhie, Vadim Kamenetsky	Submit two more manuscripts from Andrea Agangi's PhD thesis – quartz textures, melt inclusions and magma evolution. Submit a manuscript from Olga Vasyukova's PhD thesis – origin of quartz phenocrysts in mineralised porphyries. Conduct ALS synchrotron microanalytical study of submarine giant pumice clasts to constrain volatile exsolution and foam rupture. Submit manuscript on experimental simulation of submarine volcanic density currents. Submit manuscript on the misidentification of peperite in the Iberian Pyrite Belt and implications for ore genesis models. Submit Martin Jutzeler's PhD thesis, and two+ manuscripts. Complete trace element analyses of TVZ quartz-hosted melt inclusions, and submit a manuscript on the behaviour of metals during degassing and crystal fractionation of TVZ rhyolites. Continue sampling and logging at Olympic Dam and Stuart Shelf prospects. Date felsic intrusions and mineralisation.
P1B2	Leonid Danyushevsky	Continue work on the Panzhihua intrusion in China, as part of the JianXiang Guan's PhD project. Submit paper on collaborative study of sulfide-bearing mafic-ultramafic intrusions in Central Tianshan, Xinjiang, China. Undertake data collection, focussing on understanding the nature of parental melts of the Bushveld and Great Dyke intrusions in southern Africa.
P1B3B	Paul Davidson	Use the 3 kbar cold-seal and rapid-quench homogenisation facilities of GFZ, Germany, to homogenise melt inclusions in Fanshan apatite. Carry out a comparative study of magnetite and apatite chemistry, between the ore horizons and the intervening mafic/ultramafic units, in the Fanshan intrusion - in collaboration with Dr. Yuling Xie, University of Science and Technology, China. Submit a paper detailing the Fanshan study.
PROGRAM 2		
P2A1A	Jamie Wilkinson	Finish additional Irish basement source rock leachate analyses and prepare manuscript for publication. Carry out reflected light microscopy and XRD analysis of samples from Mt Isa, and measure Cu isotope compositions of chalcopyrite from different positions within the system.
P2A2A	Stephen Cox	Hire a new post-doctoral research fellow. Commence fieldwork on two intrusion-related ore systems. Commence evaluation of the controls on vein width and spacing in intrusion-related ore systems.
P2A2B	Jamie Wilkinson	Compile and interpret SEM-backscatter and SEM-CL images, LA-ICP-MS and PIXE analyses, and write-up for publication.
P2A2C	Jamie Wilkinson, Stuart Bull	Finish model scenarios and prepare manuscript for publication.
P2A3	Zhaoshan Chang, David Cooke, Jamie Wilkinson	Submit manuscripts on garnet compositions, gold inclusions and the origins of HS alteration and mineralisation.
P2B1A	Anthony Harris, David Cooke	Continue ongoing research (including documentation of the alteration footprint and deposit geology) at the Wafi and Golpu deposits, and the Hidden Valley and the Wau districts. Complete mineral chemistry studies, including epidote-chlorite sampling and LA-ICP-MS analysis, at Cadia - and commence studies at Namosi. Begin detailed lithogeochemistry and mineral mapping in the stacked lithocap. Commence additional lithocap studies in the extensive (20km diameter) Manus Island advanced argillic alteration. Complete an analysis of the geochemical footprint of the Cadia Valley. Continue student research at Golpu (Marc Rinne). Commence student research at Namosi (Evan Orovan). Commence Masters project at Wafi. Complete several workshops.
P2B1B	Taofa Zhou, David Cooke	Present research results at the 2011 GCA conference (USA). David Cooke, Zhaoshan Chang and Huayong Chen to visit Hefei University and do field work in May. This will include a short course and an SEG student chapter field trip to Luzong.
P2B1D	David Cooke, Richard Tosdal	Publication of the alkalic special issue of *Economic Geology*.
P2B3A	Investigations begun by the late Mike Solomon are being completed by John Walshe (CSIRO)	Complete project. Publish results in *Economic Geology* or a similar journal.
P2B3B	Bruce Gemmell	Continue research on the Fossey-Hellyer-Que River-Mt Charter (Tasmania), Jaguar (Western Australia), Doolgunna (Western Australia), Palmer (Alaska), Baiyinchang (China), Duc Bo (Vietnam), Tasik Chini (Malaysia) and Tala Hamza (Algeria) deposits. Initiate a PhD project to evaluate the geology and genesis of the ore bodies at Greens Creek, Alaska, pending approval by Hecla Mining. Commence a two-year postdoctoral study of the supergene and weathering geology above the Doolgunna VHMS deposits in Western Australia, funded by Sandfire Resources. Release results from the initial age dating throughout the Mount Read Volcanics.
P2B3C	Bruce Gemmell	Hold a review meeting - likely to be held at PDAC in March or GC-MAC in May.
P2B3D	Bruce Gemmell	Continue PhD project at Brothers volcano, in the Tonga-Kermadec arc. Confirm participation by CODES' researchers on an oceanographic cruise to Palinuro Seamount, Italy. Bruce Gemmell to give an invited talk at a special symposium at GAC-MAC (Ottawa, Canada), honouring the contributions of Professor Steven Scott to modern and ancient VHMS deposits.
P2B4	Garry Davidson	Complete final report for the Coronation Hill U-PGE-Au system. Define Coronation Hill work program for AMIRA P1031 project. Complete submission of Prominent Hill with Geoscience Australia.

PROJECT	LEADER(S)	ACTIVITY PLAN
PROGRAM 3		
P3A1C	Jeff Foster, Peter Fullagar	Continue development of Vpem3D including, forward modelling with conductivity gradients, downhole and multicomponent TEM capability and optimise code.
		Nominate and commence work on site studies.
P3A2A	Anya Reading	Submit publication on pilot project (ASET1).
		Establish processing methodology for 3D ambient seismic structure, and prepare publication(s).
		Begin new near-mine ambient seismic project: tentative agreement with OZ Minerals for work at Prominent Hill / Honours student support.
		Begin new in-mine seismic interferometery project: tentative agreement with IMS and Newcrest, Cadia / Honours student support.
P3A3A	Anya Reading	Feature article for ASEG publication *Preview*.
		PhD student Matthew Cracknell to continue work focussing on spatial data structures.
		Prepare a publication based on Hierarchical Bayes inference for downhole data.
P3B1A	David Cooke, Bruce Gemmell, Zhaoshan Chang	Distribute AMIRA proposal P1060 in February.
		Repeat final P765A sponsors meeting in Santiago, Chile, on March 28th, for South American sponsors.
		Secure funding & commence P1060 project with a start-up meeting in Hobart, during April.
		Sponsors field meeting in USA is tentatively scheduled for October 2011.
P3B1C	Bruce Gemmell, David Cooke	Complete and submit Hugo Galvan's PhD thesis on the Palmarejo epithermal deposit in Mexico.
		Complete and submit Lindsey Clark's PhD thesis on the Kencana epithermal deposit in Indonesia.
		Complete and submit Bronto Sutopo's PhD thesis on the Martabe epithermal deposits in Indonesia.
		Continue the post-doctoral study: Enabling Blind Exploration - Identifying Hidden Structure with Faults, Fractals and Geomorphology.
P3B2A	Ross Large, Stuart Bull	Report to AMIRA P1041 sponsors on results from pyrite-gold case studies at McPhillamys, NSW; West Wits Carbon Leader Reef, South Africa; and Chatree, Thailand.
		Undertake new pyrite-gold case studies at Martabe, Indonesia; Hope Bay, Canada; and Geita, Tanzania.
		Write-up Kumtor and Otago research for publication.
		Continue St Ives, Homestake and Geraldton PhD studies.
P3B3A	Andrew McNeill, Bruce Gemmell	Finalise report.
		Prepare publication on results.
P3B5A	Jeff Foster	Finalise analyses and complete reporting.
P3B5B	Jeff Foster	Submit publications on work completed to date.
		Complete analyses of Jinchuan samples.
P3B5C	Jeff Foster	Collect additional whole-rock and mineral chemistry (olivine data) from the Avebury deposit and host sequences.
		Date skarns using apatite and sphene.
P3B6A	Tony Webster	Develop Leapfrog models of grade and lithology for Centre Pit and South Deposit and integrate with existing mapping to produce interpretative geological level plans and sections.
		Ore texture study of Centre Pit and South Lens.
PROGRAM 4		
P4A1	Mansour Edraki	Prof. Bernd Lottermoser (New Star appointment) to develop a research team capable of building links between other major themes.
P4A2	Italo Onederra, Simon Michaux	Refine inputs into IFragX and test the sensitivity of the models by a combination of trial blasting and results derived from material processed via a compressed air cannon.
P4A3	Toni Kojovic	Undertake further research through scoping and case studies to effectively calibrate key indices in a real world environment.
		Further expand blend response modelling research.
P4A4	Dee Bradshaw	Develop a series of image analysis tools and software to further model mineral form and rock texture.
		Continue small-scale flotation test work and finalise protocols.
		Conduct further test work on materials from Prominent Hill and Cadia East.
P4A5	Dave Robinson, Matthew Jeffrey	Expand diagnostic leaching to build additional outputs that may be used to create environmental indices or proxies sensitive to the distribution and leachability of deleterious elements.
		Further develop a diagnostic leach protocol.
		Develop an integrated process that may effectively differentiate between a range of copper-bearing minerals – bornite, in particular.
		Develop robust numerical models and simulations.

PROJECT	LEADER(S)	ACTIVITY PLAN
P4A6	Ron Berry	Introduce further enhancements, such as simultaneous and sequential data analysis, for DomAIn.
P4A7	Steve Walters	Conduct case studies at a number of world-class ore deposits in Chile, Australia and Colombia.
PROGRAM 5		
P5A1	Sebastien Meffre, Leonid Danyushevsky	Improve the interface design between the laser and the mass-spectrometer to obtain more precise Pb isotopic compositions by LA-ICP-MS.
		Experiment with trapping particles generated during ablation to obtain more precise Pb isotopic compositions by LA-ICP-MS.
		Continue with collision cell developments by both solution and laser.
P5A2	Marcel Guillong, Leonid Danyushevsky	Develop apatite U-Pb geochronology standards.
		Develop protocols for determining the size of Au and other inclusions detected during LA-ICP-MS analyses.
P5A3	Bence Paul, Janet Hergt	Develop and test new protocols for the in-situ analysis of Mo isotope compositions in molybdenite grains.
P5A4	Janet Hergt, Bence Paul	Complete analysis of the Rainbow vent field samples exploring the variation in Cu isotope compositions in fall-out plume sediments with increasing distance from the vents.
		Compare chimney material from Rainbow with samples from PACMANUS to examine what influence, if any, the composition of the basement lithology has on the Cu isotope composition of vent products.
		Conduct combined stable isotope analysis (Cu + Mo) on a suite of hydrothermal sediments from the East Pacific Rise and Juan de Fuca Ridge.
P5A4A	Garry Davidson	Analyse several well understood synthetic composites, using different acid digests and time periods of reaction, to establish the best procedure for the analysis of mixtures of mono-sulfides, di-sulfides, and low levels of sulfate in carbonate.
		Apply the technique to samples that are well characterised and imaged (Mt Polley Cu-Au and Sunrise Dam Au deposits), but were not 'riskable' until the technique modifications were proven.
P5B1	Jamie Laird	In-situ growth of free gold on both real and synthetic junctions, after first selecting or generating likely seed locations, respectively.
		Submit several high-impact research papers on the main outcomes of the past two years.
P5B2	Jamie Laird	Bring the new nuclear microprobe chamber and data collection system online.
		Further improve the accuracy of PIXE and luminescence analysis of fluid inclusions and the surrounding host material.
P5B2A	Jamie Wilkinson	Measure volume of inclusions using spindle stage and nanoCT scanning.
		Synthesise information and write-up for publication.
P5B3	Chris Ryan	Test and implement the new coil heater system for mAESTRO.
		Install the mAESTRO system into the second hutch at the XAS beamline, AS.
		Develop routines for fully automatic operation, plus temperature and pressure control.
		Construct a new Maia-384 detector board for improved energy resolution.
		Conduct tests using a new silicon-drift detector (SDD) array prototype that provides a path to 2x better energy resolution and count-rate throughput.
		Implement XANES imaging into GeoPIXE package.
		Develop an adapted Maia-384 platform for the NMP for PIXE imaging.
		Upgrade the NMP vacuum chamber to accommodate Maia, plus a new stage.
		Demonstrate parallel processing of Maia data in the GeoPIXE software.
P5B4	Stacey Borg	The following actions are planned via the Australian Synchrotron:
		Develop standard procedures for extraction and analysis of XANES spectra from high resolution XRF images.
		Investigate Fe, As, Cr and V redox state using XANES from XRF images of pyrite, biotite and ilmenite samples.
		Integrate XANES image stack analysis into GeoPIXE.
		Study the solubility and chemistry of Au in bromide rich solutions at high pressure and temperature (ESRF or mAESTRO).
P5C2	Anya Reading	Develop computer-corrected enhanced images generated by LA-ICP-MS.
P5C3	Leonid Danyushevsky	Release Petrolog v.3.2, containing a range of petrological tools.

IMAGE DETAILS

SEQUENCE OF IMAGES ARE FROM TOP TO BOTTOM, LEFT TO RIGHT ON INDICATED PAGE

Cover

FRONT: Drill core showing pyrite, sericite-hematite vein in porphyry.

Grange Resources' Savage River operation.

BACK: Drill core at BHP's Escondida mine, Chile.

Outcrops of Cambrian sequences at the Ironbound Range, SW Tasmania – image continues to bottom, left corner of page.

Zhaoshan Chang lithocap sampling in the Philippines.

Dan Gregory collects core samples from the River Derwent, Hobart.

Introductory Pages

PAGE 2: Chris Allen on the coast near the Ironbound Range, SW Tasmania.

Stained potassium feldspar.

Zhaoshan Chang and Jamie Wilkinson, sampling at Cerro Cocanes in the Yanacocha district, Peru.

Director's Report

PAGE 5: Director, Ross Large.

Fundamental Research to Applied Outcomes

PAGE 7: Stephen Cox (right), ANU, leading a short course at CODES on fracture controlled hydrothermal systems. The student is Charles Makoundi.

Ironbound Range, SW Tasmania.

Bruce Gemmell (right) with John Thompson, Teck Resources, at the CODES booth, SEG Meeting, Keystone, Colorado.

Staff & Management

PAGE 9: The Advisory Board meeting in June.

Student Projects

PAGE 13: Paul Polito, Anglo American, with Fiona Best at the Phantom Creek tenement, north Queensland.

Program One/ Location

PAGE 18: Matthew Island volcano in the south-eastern tip of the Quaternary volcanic chain of the New Hebrides island arc.

PAGE 22: Group attending final meeting of the Ore Deposits of SE Asia project.

Titanium zonation in quartz eye.

PAGE 24: Vadim Kamenetsky, Jocelyn McPhie and Nick Green (BHP Billiton) inspecting drill core samples at Olympic Dam.

Dogashima coastal formation, Izu Peninsula, Japan.

PAGE 25: Laminated mudstone in the Olympic Dam breccia complex.

Takayuki Manaka inspecting granites in southern Myanmar.

Program Two/ Formation

PAGE 26: Open pit at Newcrest Mining's Cadia Hill site.

PAGE 30: Yangshan iron deposit, Anhui province, China.

PAGE 31: Samples from Nihe iron deposit, Anhui province, China – two images.

David Cooke with Taofa Zhou (Hefei University), China.

PAGE 32: Core yard at OZ Minerals' Prominent Hill site.

Shelter for core logging and sampling, Wafi camp, PNG.

Mike Baker looking at core samples at Newcrest's Cadia Hill mine.

Rhizo-concretions and wind turbines, near Cape Bridgewater, Victoria.

PAGE 34: Basalt tumuli, Wallacedale, Victoria.

Hematite-magnesium carbonates and limonite.

Series of lava flows with brecciated margins, Cape Bridgewater, Victoria.

PAGE 35: Stained potassium feldspar.

Program Three/ Discovery

PAGE 36: Chris Allen on a field trip to SW Tasmania.

PAGE 38: Huayong Chen in the Casale district, Chile.

Gabe Sweet (Lakehead University) mapping the Black Mountain porphyry, Baguio district, Philippines.

Ironbound Range, SW Tasmania.

PAGE 41: Ross Olsen on ASET2 field deployment.

Aerial views of Grange Resources' Savage River site.

PAGE 44: Cerro Casale district, Chile.

Final meeting of AMIRA project P765A.

PAGE 45: Cathedral Peak, Cerro Casale.

Program Four/ Recovery

PAGE 46: Drill core at BHP's Escondida mine, Chile.

PAGE 48: Angus McFarlane underground at Newcrest's Telfer Au-Cu mine, Western Australia.

Underground at Newcrest's Telfer Au-Cu mine, Western Australia.

PAGE 50: Malachite stained rock.

Bucket shovel at BHP's Escondida mine, Chile.

Prominent Hill site – photo courtesy of OZ Minerals.

PAGE 52: SAG/AG mills at Wiluna Gold Mine, Western Australia.

Prominent Hill site – photo courtesy of OZ Minerals.

PAGE 53: Conveyers at Newcrest's Telfer Au-Cu mine, Western Australia.

Program Five/ Technology

PAGE 54: Marcel Guillong working with the new Agilent 7700 quadrupole mass spectrometer.

Map of Fe57 taken from a multi-element laser map of a pyrite mineral grain. Sample is from the epithermal Ag-Au deposit at Palmarejo, Chihuahua, Mexico.

Dan Gregory collects core samples from the River Derwent, Hobart.

Ian Little using the new Resonetics Resolution M50 laser microprobe.

PAGE 57: Sarah Gilbert using the Agilent 7500 ICP-MS.

PAGE 61: CSIRO Nuclear Magnetic Resonance (NMR) laboratory in Melbourne.

Graduate Research & Training

PAGE 63: Graduate Research Co-ordinator, Jocelyn McPhie, aboard one of the helicopters taking MEconGeol students to White Island, New Zealand.

A selection of PhD graduates and supervisors (L – R. Ana Liza Cuison, David Cooke, Jocelyn McPhie, Heidi Pass, Jacqueline Blackwell, Susan Belford, Adam Bath, Garry Davidson.

Students from all parts of the world taking part in the Ore Deposit Models short course.

Outreach

PAGE 64: The new Gemnasium, featuring rocks from around the world.

Taroona Cubs visit the lapidary facilities at CODES.

Two young cubs engrossed in an educational game with rocks.

PAGE 65: Andrew McNeill addresses the School for Seniors at Rosny Library.

A student from Calvin Christian School jumps and stomps on the floor to simulate the effects of an earthquake as part of a seismology demonstration.

Rob Scott talks about rocks and fossils to a group from Montagu Bay Primary School.

Teachers conduct experiments during a TESEP workshop.

Director, Ross Large, in the CODES' rock garden 'talking geology' to a group from the Fahan School for girls.

Michael Roach explains some of the intricacies of seismology during the UTAS Career Advisor Symposium.

Performance Indicators

PAGE 71: Coast near Ironbound Range, SW Tasmania.

Appendices

PAGE 93: David Cooke with Taofa Zhou (Hefei University) and Zhaoshan Chang examining the Longqiao skarn, Anhui province, China.

PLEASE NOTE: IN VARIOUS PLACES THROUGHOUT THIS PUBLICATION, IMAGERY HAS BEEN USED FOR GRAPHIC PURPOSES ONLY. CAPTIONS HAVE NOT BEEN PROVIDED IN THESE INSTANCES.

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